POLITECNICO DI MILANO
Scuola del Design

Master of Science in Interior and Spatial Design

THE FUTURE OF INTERIORS
AN EXPLORATION OF SUSTAINABLE MATERIALS AND PRACTICES

THESIS SUPERVISOR
Prof. Barbara Del Curto

THESIS ADVISOR
Prof. Matti Kuttinen
Prof. Giulia Maria Gerosa

AUTHOR
Elena Salot
Matr. 915320

15th December 2020
Accademc Year 2019/2020

Abstract

ENG

Today's growing population and consumption patterns are exceeding the environment threshold, diminishing the quality of the world in which we now live and threatening the well-being of future generations. Humans' increased presence is indeed driving economic growth, which leads to an increase in global demand for goods and services and consequently brings to a rise in resource consumption. We are using more resources than the ones that Earth can provide, causing significant repercussions on the environment, and provoking unprecedented environmental changes. However, it is still possible to slow down these ill-fated changes by introducing more efficient and conscious use of resources. The construction sector, with its substantial use of materials and energy, can play a prominent role in these virtuous dynamics. Interior designers, as figures acting in this sector, recommend, choose, and use materials and products in their everyday activities, and should thus be aware of their environmental impacts. Hence, this work aims to increase interior designers' awareness of sustainability, stressing the relevance of their choices, and underlining the necessity of shifting towards more responsible and innovative solutions. The dissertation explores the environmental sustainability of materials and products used in the practice of interior design and delineates strategies to develop environmentally sustainable interiors.

ITA

Il costante incremento della popolazione mondiale e la diffusione di modelli di consumo eccessivi stanno mettendo a rischio l'ecosistema terrestre, incidendo negativamente sul suo equilibrio e minacciando gravemente le prospettive di benessere delle generazioni future. L'incremento demografico favorisce infatti una disordinata crescita economica che a sua volta genera un aumento della domanda di beni e servizi e, di conseguenza, un incremento nel consumo di risorse. Da tempo l'umanità sta utilizzando più risorse di quelle che la Terra può fornire causando ripercussioni consistenti sull' ecosistema terrestre e provocando cambiamenti climatici e ambientali senza precedenti. Nonostante tutto ciò è ancora possibile rallentare questi nefasti cambiamenti introducendo un uso più efficiente e consapevole delle risorse e, proprio il settore delle costruzioni, con il suo grande uso di materiali ed energia, può svolgere un ruolo di primo piano nel favorire queste dinamiche virtuose. I designer di interni, in quanto figure operanti in questo settore, si trovano quotidianamente a dover scegliere, consigliare ed impiegare materiali e prodotti e dovrebbero quindi essere consapevoli dell' impatto ambientale. Questo progetto di tesi mira dunque ad aumentare la consapevolezza dei designer di interni sulla sostenibilità ambientale, sottolineando la rilevanza delle loro scelte ed enfatizzando la necessità di adottare soluzioni più innovative e responsabili. Nell'elaborato viene esplorata la sostenibilità ambientale di materiali e prodotti utilizzati nella pratica dell' interior design e sono delineate strategie per sviluppare interni ecosostenibili.

Table of contents

Table of figures

CHAPTER 3 ENVIRONMENTALLY SUSTAINABLE INTERIOR DESIGN

CHAPTER 4 SUSTAINABILITY IN PRACTICE

1

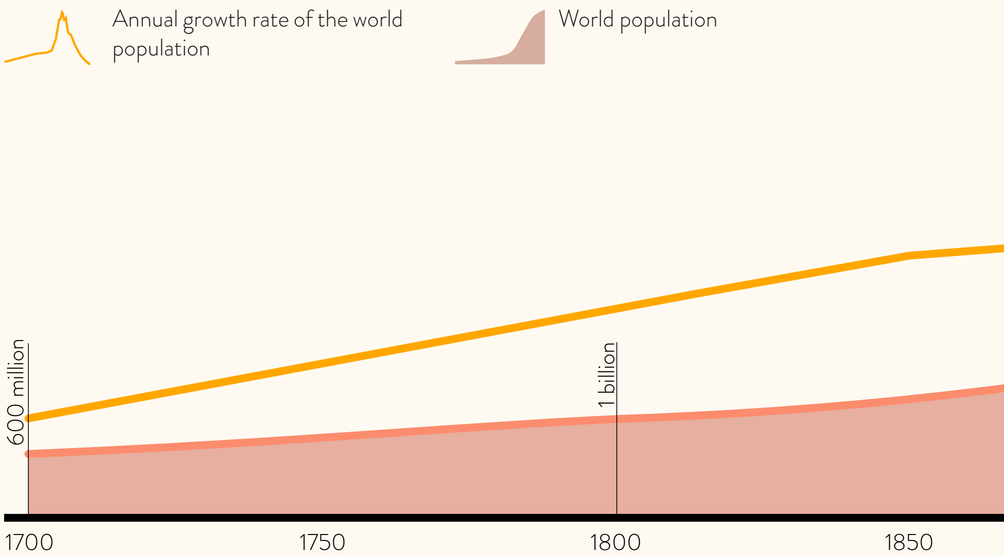
Materials in today's world

1.1 Population, consumption and their environmental impacts

There are 7.7 billion people currently living on Earth and, despite a continued slowdown in the global birth rate, there will be more than 9.7 billion in 2050 (United Nation, 2019). Population started this rapid growth after the Second World War, and since then we have been adding a billion people to the global population every 12-15 years. (Figure 1).

Our increased presence did not come without consequences. In fact, every human activity has some repercussions on the environment in which we live, and despite the environment has some capacity to cope with this, we are currently approaching the limits (Ashby, 2012, p 8).
The following graphs (Figure 2) show socio-economic and environmental trends from 1750 to 2010 and display how human activities are exceeding the environment threshold, diminishing the quality of the world in which we now live and threatening the wellbeing of future generations (Ashby, 2012, p 8).

Figure 1.1
World population trend



Adapted from Our World in Data based on History Database of the Global Environment, United Nations (UN) and UN Population Division (2019 Revision)

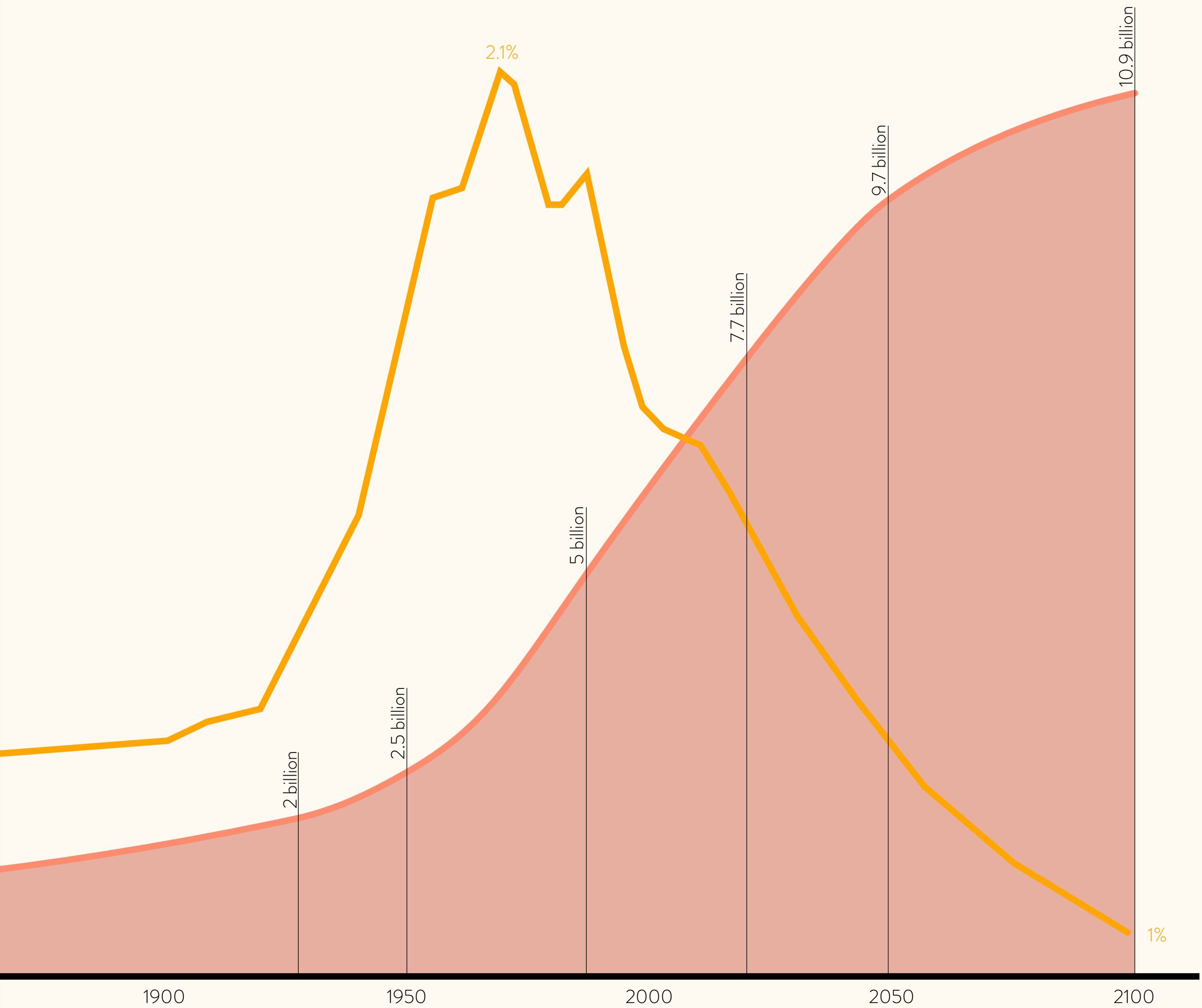
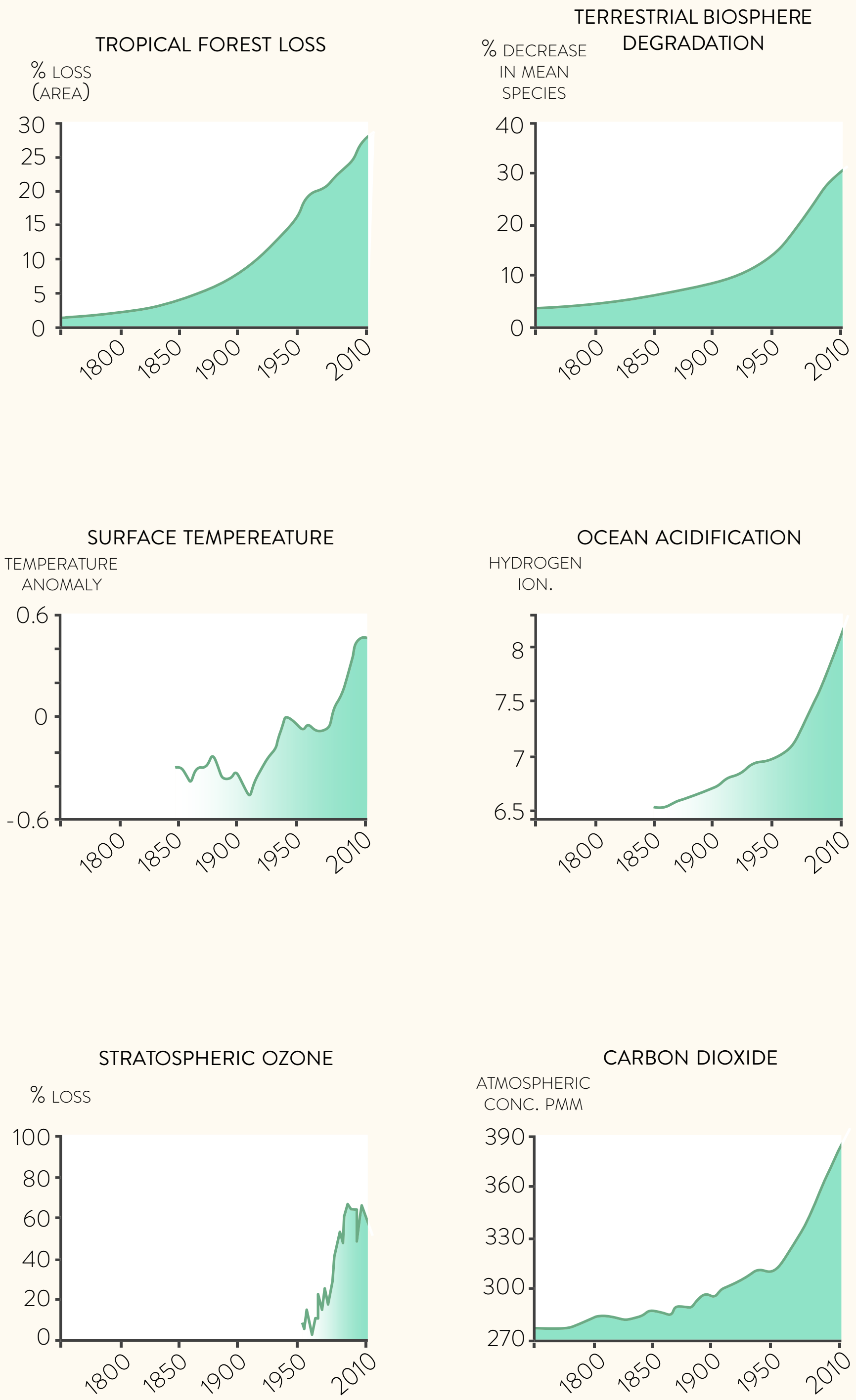

2.1%
10.9 billion
9.7 billion
7.7 billion
5 billion
2.5 billion
2 billion
1%
1900
1950
2000
2050
2100

Figure 1.2

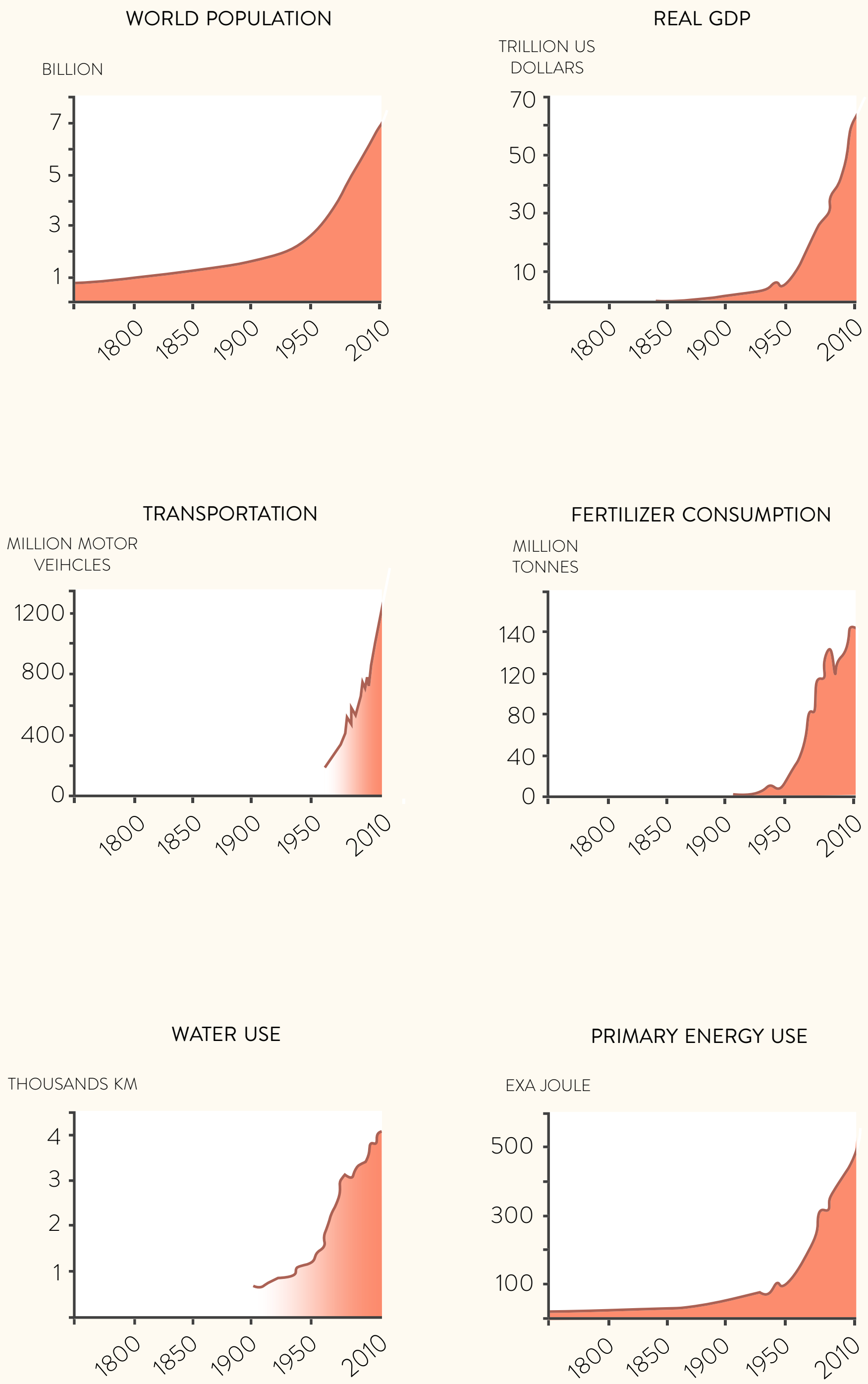
Earth systems trends



Note: trends from 1750 to 2010 in globally aggregated indicators for the structure and functioning of the Earth System. Adapted from Broadgate, W., Deutsch, L., Gaffney, O., Ludwig, C., & Steffen, W. (2015). *The trajectory of the Anthropocene: The great acceleration. The Anthropocene Review.*

Figure 1.3

Socio - economic trends



Note: trends from 1750 to 2010 in globally aggregated indicators for socio - economic devel - opment. Adapted from Broadgate, W., Deutsch, L., Gaffney, O., Ludwig, C., & Steffen, W. (2015). *The trajectory of the Anthropocene: The great acceleration. The Anthropocene Review.*

What emerges from these graphs is that while economic activities, population and GDP (Gross Domestic Product) continued to grow at a rapid rate, the Earth system kept changing and degrading. The Earth System indicators began increasing after the industrial revolution and continued their longterm rise reaching exceptional levels. By observing and comparing the two groups of charts, it becomes evident that the fundamental shifts in the state and functioning of the Earth system, which have occurred after the mid-20th century, are beyond the range of variability of the Holocene and are driven by human activities (Broadgate et al., 2015). Humans have always been modifying the terrestrial biosphere to a certain extent but never with the same speed and intensity we have been doing it during the past century. This, brought some scientists and researchers to define this epoch, from the 1850s until today, as the Anthropocene, the era in which humans altered atmospheric, geologic, hydrologic, biospheric and many other earth system processes.

It is then clear that the recent unprecedented environmental changes have been caused by the rapid growth of human population and the associated consumption of resources. Indeed, global resource depletion scales with population and per-capita consumption. Today's global population is using more resources than the ones that Earth can provide. Our demands are so high that we are now using those resources at 1.7 times the rate that the Earth can renew them (Population matters, 2020). The OECD[1] Global material resources outlook to 2060 foresee that global primary materials use, and thus global primary materials extraction, will double in the coming decades, reaching 167 Gigatonnes in 2060. According to the Organisation for Economic Co-operation and Development (2018), in the years ahead, a growing population with higher incomes will drive economic growth but also a strong increase in global demand for goods and services. Which means higher demand for resources such as energy and materials, whose chains have a wide range of environmental implications. Consequently, the greater the population, the greater the consumption of resources, the greater the repercussions on the environment.

Material consumption, as population growth, will be different in different countries and emerging and developing economies, since they will face higher economical growing rates, are projected to play a major role (Organisation for Economic Co-operation and Development, 2018). As a matter of fact, not all counties contribute to Earth depletion in the same way and, by considering global aggregates only, strong equity issues are masked. Differentiated graphs would show that most of the population growth since 1950 has been in the so-called BRICS (Brazil, Russia, India, China, South Africa) and other countries, but the world's economy (GDP), and hence consumption, has been strongly dominated by OECD countries. As the middle classes in the BRICS nations grow, e.g. China, the situation changes but inequalities in income and wealth, both within and between countries, continue to be a significant problem, with consequences for individual and societal wellbeing (Broadgate et al., 2015).

Nevertheless, some regions are already witnessing unusual extreme temperatures, sea level rising, oceans acidification, water scarcity and record breaking

Note

[1] The Organisation for Economic Co-operation and Development (OECD) is a group of 34 member countries that discuss and develop economic and social policy. OECD members are democratic countries that support free-market economies.

levels of greenhouse gases. Continuing on this path will cause long-term changes in the climate and earth systems, jeopardizing the future of the next generations.
In the past decades, countries all over the world started taking action and, in 2009, Europe announced her will to become a net-zero economy[2] by 2050. The objective is quite ambitious and the debate on how to achieve it is intense. Most of the polices and roadmaps proposed so far are mainly focused on increasing energy efficiency and deploying low-carbon energy sources. Both are crucial, but when it comes to industry, a major source of emissions, they offer only a partial solution. Additional strategies are needed to address the substantial emissions caused by materials (Material Economics, 2018).

Note

[2] Net-zero economy means that any residual greenhouse gas (GHG) emissions from the economy are completely offset by removals, through activities such as reforestation or bioenergy with carbon capture and storage (Crouch et al., 2019).

1.2 Our material and energy dependence

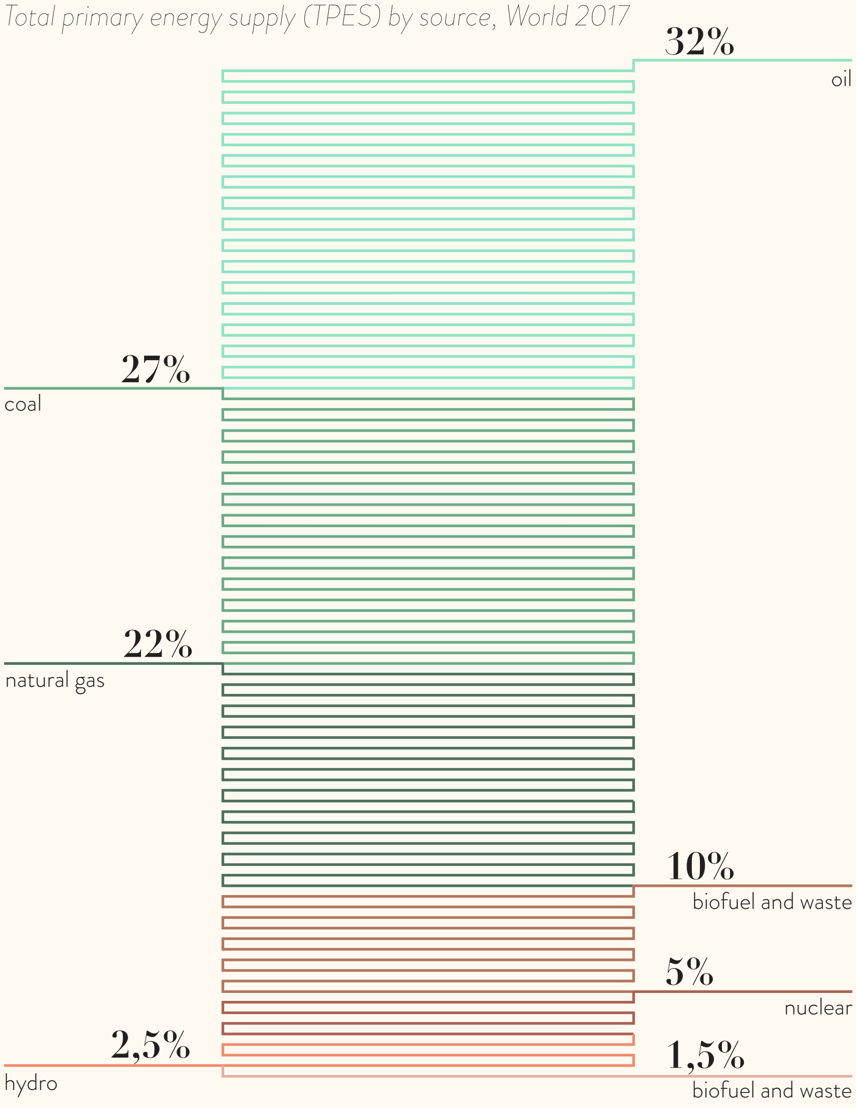
Materials are resources that have enabled the advance of mankind from its earliest beginnings and played a crucial role in advancing technology. First, we relied on renewable materials and then, when new ones were discovered, we started consuming non-renewable displaced resources. Our "relationship" with materials changed with the industrial revolution, which transformed the economics of materials from precious to commodity and made us dependent on them. Materials are thus fundamental to build infrastructures, transport systems, buildings and factories, and to produce and package consumer goods, which are a direct result of countries development and economic growth. Materials are thus the heart of maintaining high standards of living and a healthy industrial sector, which is widely seen as crucial for economic competitiveness (Material Economics, 2018). It is thus no surprise that economic development around the world has kept increasing demand for them. Though, this demand, coupled with the world's continued population growth, consumes resources at an ever-increasing rate (Ashby, 2012, p 2).

The growth of global population and affluence will increase the demand for materials but how much "matter" is still available? Since we live on a finite planet our resources are finite but, at the same time, it is unlikely that we will run out of them. Hence, it is important to distinguish between reserves and resources. Reserves can be defined as that part of a known material that can be extracted or harvested, legally and economically using today's technology. It is an economic construct that grows and shrinks under varying economic, technical, and legal conditions and therefore it does not describe the total quantity present. A resource base instead, is the real total and it includes not only the current reserves but also all other usable deposits that might be revealed by future prospecting and that, by various extrapolation techniques, can be estimated. (Ashby, 2012, p 32).

Global stocks of most of the materials used to provide buildings, infrastructure, equipment and products are still sufficient to meet anticipated demand, but the environmental effects of materials production and processing, particularly those related to energy, are rapidly becoming critical (Allwood, 2011). As resources become depleted, it takes more energy to extract them, and they become more energy-intensive. Energy is inseparable from the making of materials, their manufacture into products, their use, and their ultimate disposal (Ashby, 2012, p 20). Consequently, the same way we depend on materials we depend on energy.

Figure 1.4

Total primary energy supply (TPES) by source, World 2017



Note: adapted from International Energy Agency (https://www.iea.org/data-and-statistics)

With cheap, carbon-free energy the material supply could continue (almost) forever but today's world total primary energy supply is dominated by oil 32%, coal 27% and natural gas 22% (International Energy Agency, 2019), all resources that are neither carbon-free, boundless and cheap (Ashby, 2012). The energy supply sector is indeed the largest contributor to global GHG emissions, contributing for approximately 40% of total anthropogenic GHG emissions.

Achieving zero-carbon energy is thus crucial to achieve the Paris Agreement's[3] long-term goal of a global economy with zero net GHG emissions but it is not enough. It is high time that climate policy looks not just at how materials are produced, but at ways to reduce demand for new materials and make more of the materials we have already produced (Material Economics, 2018).

Note

[3] The Paris Agreement is the first-ever universal, legally binding global climate change agreement, adopted at the Paris climate conference (COP21) in December 2015. The agreement sets out a global framework to avoid dangerous climate change by limiting global warming to well below 2°C and pursuing efforts to limit it to 1.5°C (.European Commission, 2020).

1.3 Towards a circular economy and greater material efficiency

As aforesaid, much interest in achieving climate goals has been placed on energy but also reconsidering our handling of materials can provide more than viable solutions.

Nowadays, our use of natural resources follows a linear path characterised by the sequence "take-make-use-dispose". Increasing population, rising affluence and the limited capacity of the planet to provide resources and absorb waste argues for a shift from this model. How could we make better use of the materials and products already produced and so reduce our need for new production? The concept of the 'circular economy' offers precisely this opportunity. The circular economy is a model of production and consumption designed to benefit businesses, society, and the environment. It rethinks the relationship between the natural eco-system and the technological system, aims to redefine growth focusing on positive society-wide benefits and call for decoupling economic activity from the consumption of finite resources. It involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products as long as possible (European Parliament, 2018). Thus, the "circularity" concept is based on the principles of designing out waste and pollution, keeping products and materials in use, and regenerating natural systems (Ellen Mac Arthur Foundation, 2020). A circular material economy wills to bring a shift in the way we think of materials, moving from the idea of consuming them to the one of using them. Indeed, in this system materials are not seen as a disposable commodity, but rather as a valuable asset to be tracked, conserved.

Figure 1.5 shows circularity strategies that look at materials in this way and aspire to reduce consumption.

Figure 1.5

Circularity strategies within the production chain, in order of priority

CIRCULAR ECONOMY

INCREASING CIRCULARITY

Smarter product use and manufacture	R0	Refuse	Make product redundant by abandoning its functin or by offering the same function with a radically different product
	R1	Rethink	Make product use more intensive (e.g. through sharing products, or by putting multi-functional products on the market)
	R2	Reduce	Increase efficiency in product manufacture or use by consuming fewer natural resources and materials
Extend lifespan of product and its parts	R3	Re-use	Re-use, by another consumer, of discarded product which is still in good condition and fulfils its original function
	R4	Repair	Repair and maintenance of defective product so it can be used with its original function
	R5	Refurbish	Restore an old product and bring it up to date
	R6	Remodel	Use parts of discarded product in a new product with the same funciton
	R7	Repurpose	Use discarded product or its parts in a new product with a different function
Useful application of materials	R8	Recycle	Process materials to obtain the same (high grade) or lower (low grade) quality
	R9	Recover	Incineration of materials with energy recovery

LINEAR ECONOMY

INNOVATION IN CORE TECHNOLOGY

INNOVATION IN PRODUCT DESIGN

SOCIAL INSTITUTIONAL CHANGE

INNOVATION IN REVENUE MODEL

Note: circularity strategies to reduce the consumption of natural resources and materials, and minimize the production of waste, ordered for priority according to their levels of circularity. Source: form Hanemaaijer, A., Hekkert, M., Potting, J., & Worrell, E. (2017). Circular economy: Measuring innovation in the product chain.

Transitioning to a circular economy represents a systemic shift that builds long-term resilience, generates business and economic opportunities, and provides environmental and societal benefits (Ellen Mac Arthur Foundation, 2020).
Furthermore, a more circular economy is considered indispensable for meeting global material needs without exceeding the available carbon budget (Material Economics, 2018). The Intergovernmental Panel on Climate Change has estimated a remaining 'carbon budget' for this century of around 800 billion tonnes (Gt) CO_2. This is the amount of emissions that can be emitted until 2100 for a good chance of keeping warming below 2°C – with still less for the 'well below 2°C' target set by the Paris Agreement (Material Economics, 2018, p7). Material Economics study *The circular economy: a powerful force for climate mitigation* (2018) estimates that, on current trends, materials production alone would result in more than 900 Gt of emissions. Thus, energy efficiency and low carbon energy will help but do not resolve this dilemma.

The opportunities to abate carbon emission from the material "management" emissions within the circular economy are several. Material Economics's study (2018) framed them into three major categories:

- Materials recirculation opportunities: that stands for facilitating recycling and favouring product design and end-of-life disassembly to enable high-value recovery
- New circular business models such as sharing that would enable a more intensive use of the already existing infrastructures, especially that of vehicles and buildings
- Product materials efficiency, which implies delivering the same required services with less primary production (Allwood, 2011)

Materials efficiency' potential to cut emissions has been researched by Julian Allwood and the Low Carbon Materials Processing Group (2011) and, according to their study, it would be greater and cheaper than energy efficiency. They thus pointed out six actions to make the future of materials use more efficient and sustainable. Those actions include: optimizing design in order to use less material, reduce yield losses, divert manufacturing scraps and reuse old components before recycling them, extend the lives of products and reduce final demand. The guidelines suggested by Allwood (2011) recall the ones pointed out by Ashby (2016): improving materials technology, replacing products with services, establishing new regulations, changing lifestyles and designing products with longer lifetimes that can be reused, repaired and recycled. Both aims at an economic paradigm that is not linear but rather circular.

One of the sectors in which big changes can be made to achieve materials efficiency and move towards a more circular economy is the construction and building sector.

1.4 The role of the construction and building industry

The construction industry is responsible for nearly 40% of total direct and indirect CO_2 emissions and over one-third (36%) of global final energy consumption (Global Alliance for Buildings and Construction, 2019). Given the increasing global population and the high ecological footprint of the sector, de-carbonising buildings is critical for achieving sustainable development. Green building standards, certifications, and rating systems aimed at mitigating the impacts of buildings on the natural environment through sustainable design already exist (e.g. LEED, BREEM), but greater efforts are needed. The 2019 Global Status Report for buildings and construction, outlined policies and road-maps recommendations to move towards zero-emissions, efficient and resilient buildings. Most of them, considering buildings' high energy demand and emissions, have understandably focused on the use phase, especially on energy consumption. They thus promoted energy codes and performance certifications aimed at reducing the amount of energy used and provided information to consumers about their buildings to gradually create a market for more efficient buildings (Global Alliance for Buildings and Construction, 2019).
However, the building industry is also a great consumer of materials, representing a significant share of our total use. Around 15% of total lifecycle CO_2 emissions from EU buildings today are attributable to materials and construction (Material Economics, 2018, p 144). The EU uses as much as 1.6 billion tonnes (Gt) of materials for buildings per year, which results in about 250 million tonnes (Mt) of CO_2 emissions annually. That amount is likely to grow as building stock continues to slowly expand, and as large numbers of post-war buildings require substantial renovation or replacement in the decades ahead (Material Economics, 2018, p 140). According to the Global Status Report for buildings and construction, 11% of the global energy-related CO_2 emissions are due to the manufacturing of building materials. Concrete, for example, is the main material used in constructions and despite its impacts aren't very large, its volume of use it's huge and it's responsible for 9% of total GHG emissions (Global Alliance for Buildings and Construction, 2019). How we use construction materials therefore matters greatly for future climate targets(Material Economics, 2018, p 140).

Moreover, construction and demolition waste (CDW) is one of the heaviest and most voluminous waste streams generated in the European Union (EU), accounting for approximately 25% - 30% of all waste generated in the EU. Those wastes arise from different activities that include not only the construction and demolition of buildings and civil infrastructure but also road planning and maintenance. CDW consists of numerous materials, including concrete, bricks, gypsum, wood, glass, metals, plastic, solvents, asbestos and excavated soil, many of which can be recycled. Given the technologies for the separation and recovery of those waste and the presence of a re-use market for aggregates derived from CDW, there is actually a high potential for recycling and re-use of CDW (European Commission, 2019).

Reducing the environmental impact of materials and equipment in the buildings and construction value chain is possible by taking a lifecycle approach. This means not only embracing a cradle-to-cradle[4] lifecycle approach and supporting the development of material reuse and recycling processes but also increasing buildings' longevity and adaptability, favouring disassembly at the end of life and promoting new construction techniques and business models for buildings (Material Economics, 2018). Furthermore, implementing policies and introducing information and awareness campaigns on low-carbon materials and technologies (e.g. wood and earth constructions, innovative concrete) among professionals and consumers, could increase the sustainability of building materials and products.

Note

[4] Cradle to Cradle (C2C) is about seeing garbage as an eternal resource and doing the right thing from the beginning. It is about making community and product development function in the same way as a healthy ecological system where all resources are used effectively, and in a cyclical way (as opposed to the current linear system that can be better described as a Cradle to Grave system) (Sustainability Guide, 2020).

Overall, the key measures that could reduce the demand for building materials are similar to the ones mentioned beforehand:

- Materials recirculation: recycling materials from end-of-life buildings, and designing and dismantling buildings so that high-value recycling is possible (Material Economics, 2018).
- Circular business models: increasing the useful service room materials, by extending the lifetime of buildings, and/or by increasing the utilisation of floor space through sharing and other mechanisms (Material Economics, 2018).
- Building materials efficiency: reducing the quantity of materials that are required for a given floor area. The main opportunities are to reduce waste during the construction process; reduce the amount of material in each building by avoiding over-specification and using higher-strength materials; and reusing buildings and building components (Material Economics, 2018).

Some architects and architectural practices are already following and designing according to some of those principles. The following pages feature three of them.

MADASTER FOUNDATION

In 2017 Dutch architect Thomas Rau launched “Madaster Foundation” (Madaster, 2020), a cadastre for materials which mission is to eliminate waste by providing materials with an identity. Madaster is an independent platform with free access for everyone that works as an online library of materials in the built environment. It links the identity of materials to a location and registers this in materials passport. The materials passport allows materials to keep their identities and gives information on the quality of materials, their locations, and their monetary and circular value. This makes every building into a depot of materials with a certain value and facilitates reusing materials, minimising waste, and reducing the cost of material consumption

Figure 1.6
Inspirational quote from Thomas Rau

LENDAGER GROUP

Lendager Group (Lendager group, 2020) is an architecture firm committed to circular economy and resource efficiency. This innovative company working in the built environment is specialised in cost-neutral sustainable buildings and does do by always placing sustainability at the core of everything they do, and never a cost adding factor. The firm enhances sustainability in buildings by ensuring that materials are circulated and kept at their highest possible value at all times (Lendager group, 2020). A great example of their work is The Resource Rows, the project of a new development area in Copenhagen in which Lendager Group up-cycled bricks (Figure 1.7) form the historical Carlsberg breweries and wood from the construction of Copenhagen Metro.

Figure 1.7
The Resource Rows, facade

ROTOR DECONSTRUCTION

Rotor Deconstruction (Rotor deconstruction, 2020) is a pioneering company in the field of salvaged building components, that facilitates the reuse of construction materials. The team dismantles, conditions and sells materials, as well as provides assistance to building owners, contractors and architects. Rotor is trying to kickstart a radical shift in the way architects and builders think about construction, designing for reuse from the beginning, and changing people's perceptions of the value of second-hand materials.

Figure 1.8

Rotor Deconstruction workers dismantling a tile floor

Materials and natural resources are fundamental for our survival but also for the functioning of our economy and society. Nevertheless we value them very little and exploit them with carelessness. To change our attitude towards materials and make it more sustainable it is important to understand what are materials and what sustainability means.

2

Materials, interiors and sustainability

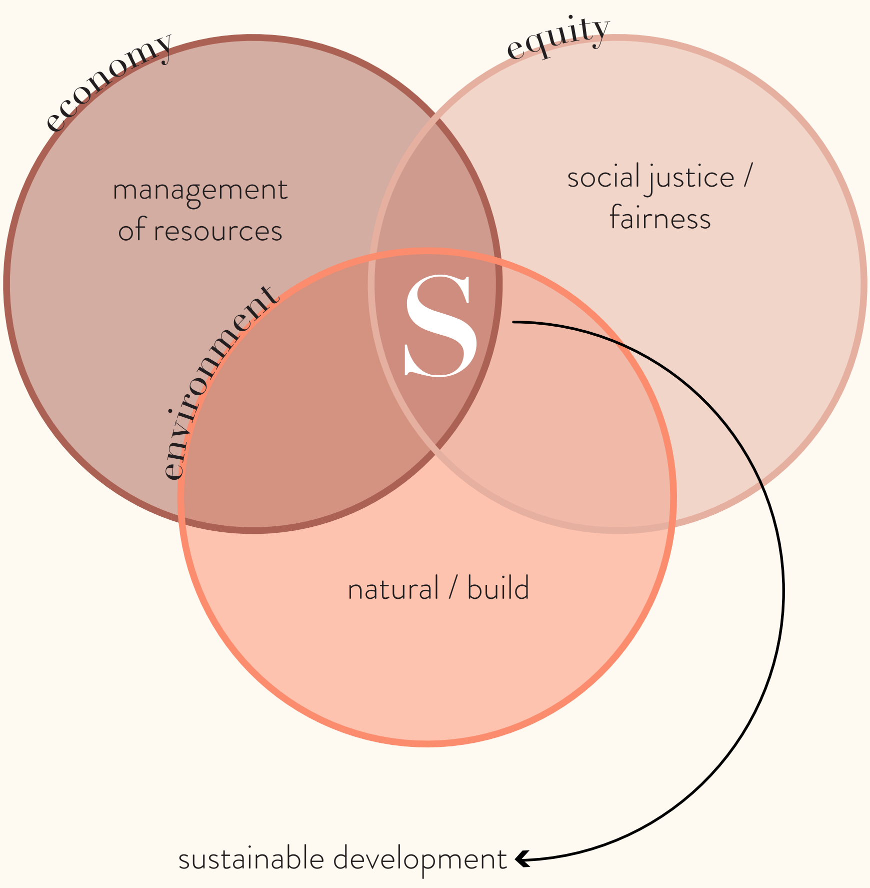
2.1 What is sustainability?

One of the goals of this thesis is to increase interior designers' awareness of sustainability, therefore is necessary to understand what sustainability means and how it has been framed in this work.
Sustainability has been defined in numerous ways. The most well-known definition is the one provided by the World Commission on Environment and Development (WCED) in 1987, where it was stated that sustainability is Economic-Development activity that "meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development 1987, p 39). This definition provides a convenient point of departure for a broad understanding of this fairly abstract concept, but it's still subject to interpretations. Thus, the WCED described sustainability as having three co-equal parts: environment, economy, and equity or society.
Environmental sustainability can be defined as the carrying capacity of ecosystems or rather as meeting human needs without compromising the health of these, while economic sustainability requires that current economic activity does not disproportionately burden future generations. From a social standpoint, social sustainability is more difficult to define but it has been described "as a positive condition within communities, and a process within communities that can achieve that condition" (Morelli, 2011, p 3). These elements favoured a deeper elaboration of the concept and led to the idea that sustainability can be achieved only by simultaneously protecting the environment, preserving economic growth and development, and promoting equity (Portney, 2015). However, these three pillars holding up the concept of sustainability, should not be considered of the same importance. In fact, without a sustainable productive environment that provides resources, it would be difficult or impossible to have a sustainable society. Similarly, a sustainable economy depends upon a sustainable flow of material, energy, and environmental resources. Without it, economic systems will fail. On the contrary, a sustainable environment doesn't need to be dependent on the existence of either society or economy and can stand alone as a sustainable system. Therefore, the basic premise of sustainability is that Earth's resources cannot be used, depleted, and damaged indefinitely because not only these resources are finite, but also because their exploitation undermines the ability of life to persist and thrive (Portney, 2015, p 4). Overall, sustainability conveys the idea that there is no trade-off between what is good for the environment and what is good for the economy because the depletion of natural resources and environmental degradation conspire to depress economic growth and development.

Nevertheless, the more precise meaning of these three sustainability parts depends on contexts and intellectual fields. The concept has somewhat different meanings in the contexts of ecology, energy, environment, agriculture, population dynamics and demographics, and economics (Portney, 2015, p 53). For this work it has been decided to consider the environmental aspect of sustainability in the context of the built environment. In detail, it will look at material and practices that can reduce the environmental burden of interior design projects and will focus on material resources and end of life possibilities.

Figure 2.1

Venn diagram of sustainable development



2.2 What is an interior?

An interior is a private or public space, permanent or temporary, characterised by a complex set of elements that determine the relationship between the space itself and the individuals who inhabit it. An interior could be the inside of a house, hotel, school, shop, museum, hospital and so on, but an interior can also be created in an outdoor environment.
Designing an interior means considering the shell of a space as a starting point for working inside of it. It means taking care of the spatial organization (layout) in relation to the activities, choose and define the space equipment and furniture, but it also means minding the whole range of intangible components such as light, sound, colours, materials and texture, that give the space a precise identity and generate different forms of relationship with users (Piccinno, 2015; Introduction: Interior design, 2018). Moreover, "interior designers have a moral and ethical responsibility to protect consumers and occupants through the design of code-compliant, accessible, and inclusive interior environments that address well-being, while considering the complex physical, mental, and emotional needs of people" (Council for Interior Design Qualification, 2019). This means that interiors have to meet more than mere functional requirements. They need to give a sense of belonging and identity and provide a pleasant sensory and psychological experience. This is achieved by carefully balancing all the various elements that characterise an interior, between themselves and with the overall context.

Of all the elements that determine an interior, the materiality of surfaces such as floors, walls and ceilings play a major role on an interior final "result", affecting both users health and experience of the space. Materials convey meaning, evoke memories and create atmosphere. For example, wooden and ceramic floors evoke different sensations and a flight of metals stairs and one of stone lead our imagination to dissimilar contexts. Consequently, when selecting materials for an interior, the designer must consider the phenomenology of space: how the user will experience and respond to the sensory qualities of the space, both physically and emotionally. This could include responses such as how it feels to touch a surface or memories that are provoked, perhaps by a smell or a particular sound. Hence, materials may also have subjective attributes that emanate from a person's experience and emotional response or that arise from social, political or culturally constructed readings of them. Additionally, apart from the five classical senses (sight, smell, touch, taste, hearing), many others have been identified as influential in interior design. These include the sense of movement; balance; proprioception, or sense of self (our position in space); the sense of life /comfort (well-being); and numinous, a sense of awe and wonder. All these experiences tend to be interconnected and holistic and give the overall feeling of the interior responses.

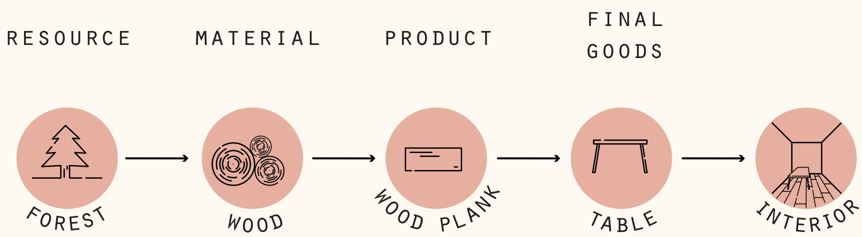
Consequently, it is major to consider not only the qualities of the materials themselves but also the atmosphere that emerge when they are juxtaposed in three dimensions (Brown, 2012). It is indeed the combinations of all the elements in relation with the overall context that influences how we perceive a space and how we feel in it, affecting our mood, and behaviour.

However, interior are not directly made from materials, but rather from the processing of them, or rather products.

Products, in this dissertation, can be described as the result of the processing of materials. Materials are obtained from resources, then processed to form products and, in the end, used in interiors. Examples of products include ceramic tiles, wooden boards and plasterboard panels but also windows, doors and the furniture present in a space. The latter, however, can be referred as final goods which are not going to be discussed in this work.
Let's take a wooden board as an example. Everything starts from the resource, the forest and its trees. When the trees are cut, their logs become wood, a material, and then, after several processes they are transformed into planks, panels and boards, that are products, which will then be used to realize final goods (chairs, tables, cabinets) and spaces.

Figure 2.3

From the resource to the interior



Note: rapresentation of the process from resource (forest), to material (wood), product (wood plank) and then final goods (furniture and interior).

2.3 What are materials?

Materials can be defined as physical substances from which things can be made from or rather as physical things having qualities that allow them to be used to make other things (Cambridge Dictionary, n.d).

Materials are characterised by properties and transformation processes. Properties are inherent to the material and delineate their behaviour in different situations. The most significant properties are the so-called functional properties and include physical, mechanical, magnetic, thermal, electrical and optical properties. Transformation processes describe how a material can be processed. They can be divided into primary processes, that are those who give the shape, and secondary processes, which are those that change the geometry and the properties of the material. As a matter of fact, transformation processes can affect the material properties and not all technologies work well with every material (Del Curto et al., 2015). Nonetheless, materials are also characterized by other features such as their applications or smart behaviour and the sensations and emotions they can transmit.

Figure 2.4

Stack of fabric rolls

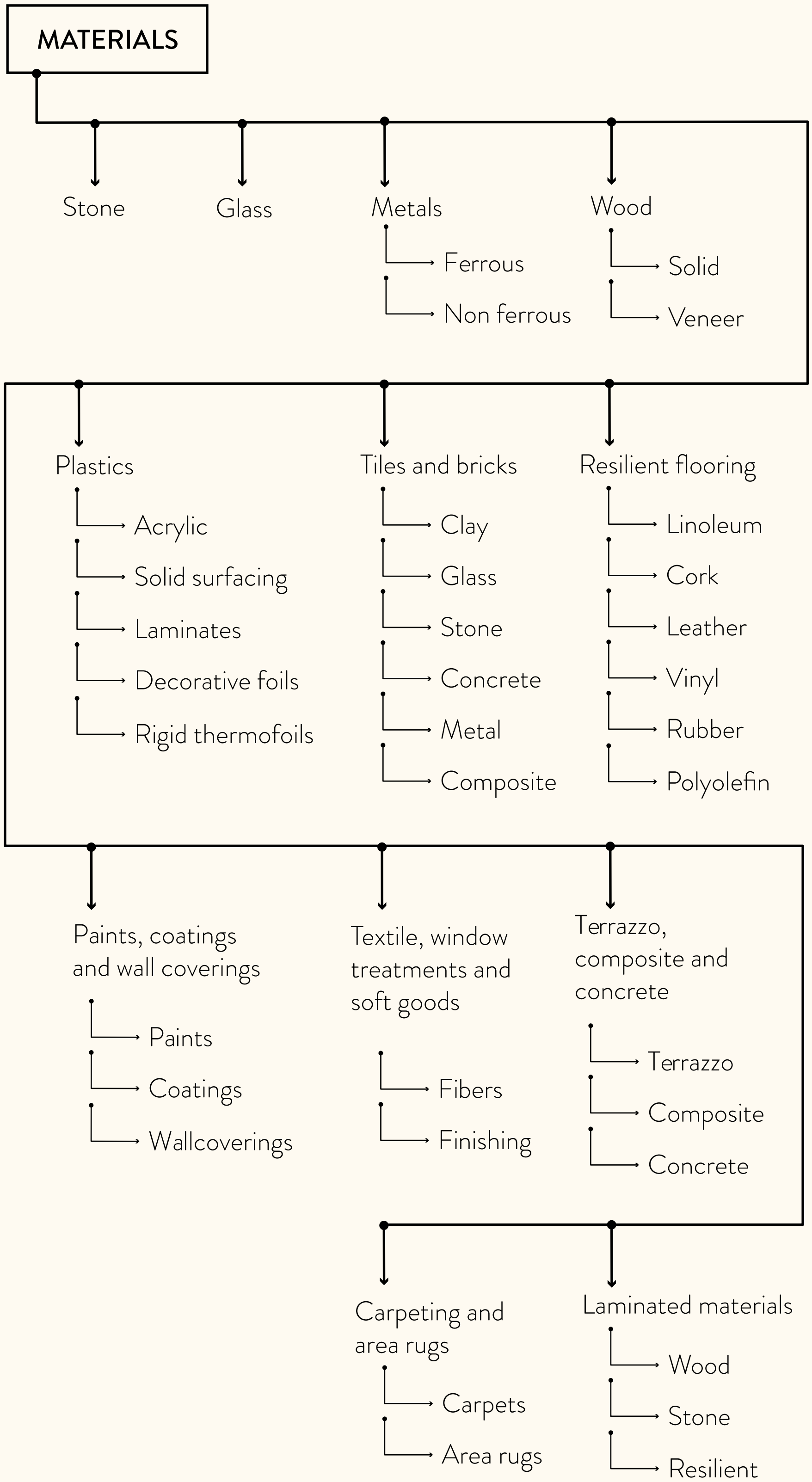
2.3.1 Materials classes

Classifying materials is a step of utmost importance. One fine classification should capture and store several materials characteristics, organize them in a way that allows rapid retrieval, present them in a creative format and allow browsing, retrieval, and combination of "bits" of information (Ashby, 2012). Materials have been organised in many different ways and different classifications can be made according to the purpose of the classification and the criteria used. In general, materials that share similar properties, transformation processes and sometimes applications, are grouped in families. Families can be further divided into classes, underclasses and then elements (materials). One of the most common classifications is the one we could broadly call scientific, that divide materials according to their mechanical and physical properties in metals, ceramics, glasses, polymers, wood, composites, natural fibres, and stone. However, materials can also be grouped according to their sensory properties, resemblance to a natural element (air, fire, earth, water), innovative content or even their intelligent behaviour. The possible classifications are several and exploring them can encourage designers to think laterally, explore the potential of materials and therefore foster innovation. In interior design, materials classification can be also made according to the type of project and the interior designer task in that specific project.
Design involves choice and choice from an enormous range of ideas and data, thus effective materials classifications can really help designers in selecting materials, undertaking a key role in the design world.

Looking at the existing literature regarding materials and interior design, several are the ways in which materials and finishes have been organized by different authors (figures 2.5, 2.6, 2.7, 2.8). Materials categorization differ also between materials libraries. Figure 2.9 and 2.10 show how materials are categorized into two material libraries, one focused on interiors and architecture and the other with no specific field.
Figure 2.11, instead, illustrate the classification by the Cambridge Engineering Selector (CES) Edupack, a set of teaching resources that support Materials Education across Engineering, Design, Science and Sustainable Development. CES provides a comprehensive database of materials and process information and a range of supporting tools resources (e.g. software, lectures, projects, and exercises).

Figure 2.5

Materials classification by Godsey L. in Interior design materials and specifications



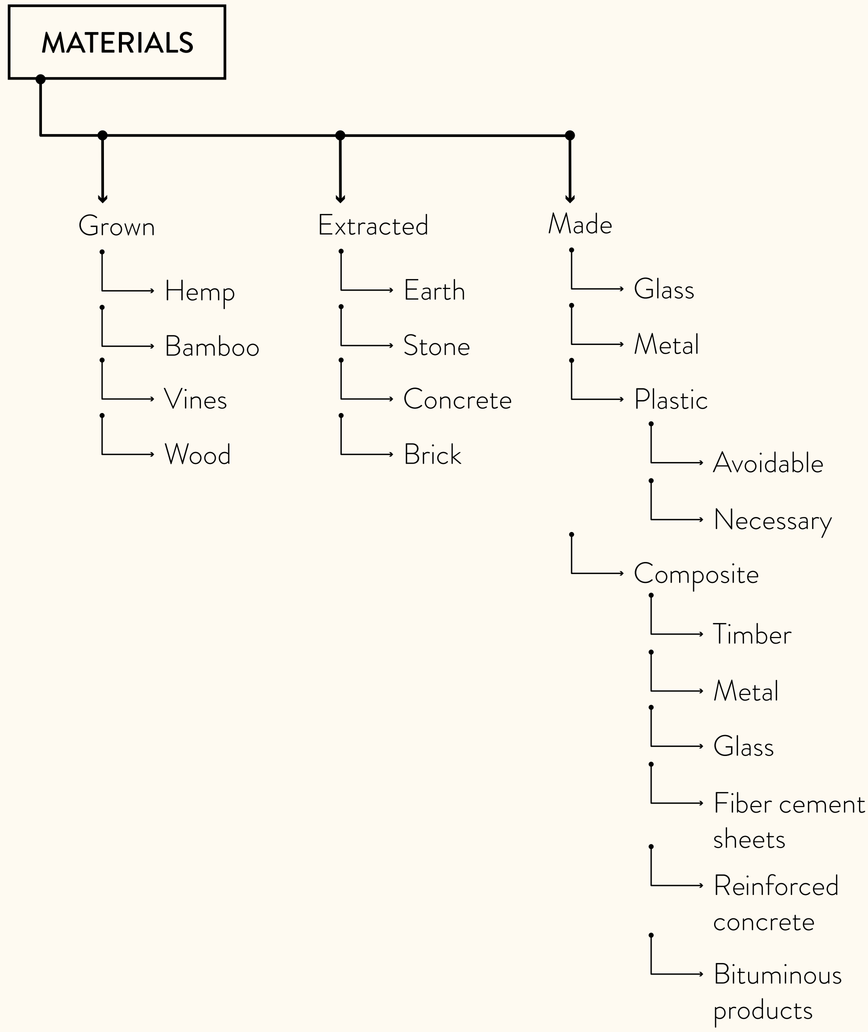
Note

Godsey' classification is quite complete and comprehend several materials and finishes but, given the great number of categories, there are many overlaps between them that makes it often confusing to browse.

Source: from Godsey, L. (2017). Interior design materials and specifications (3rd ed.). New York, NY: Fairchild Books, an imprint of Bloomsbury Publishing Inc

Figure 2.6

Materials classification by Petrovic E. in Materials for a Healthy, Ecological and Sustainable Built Environment



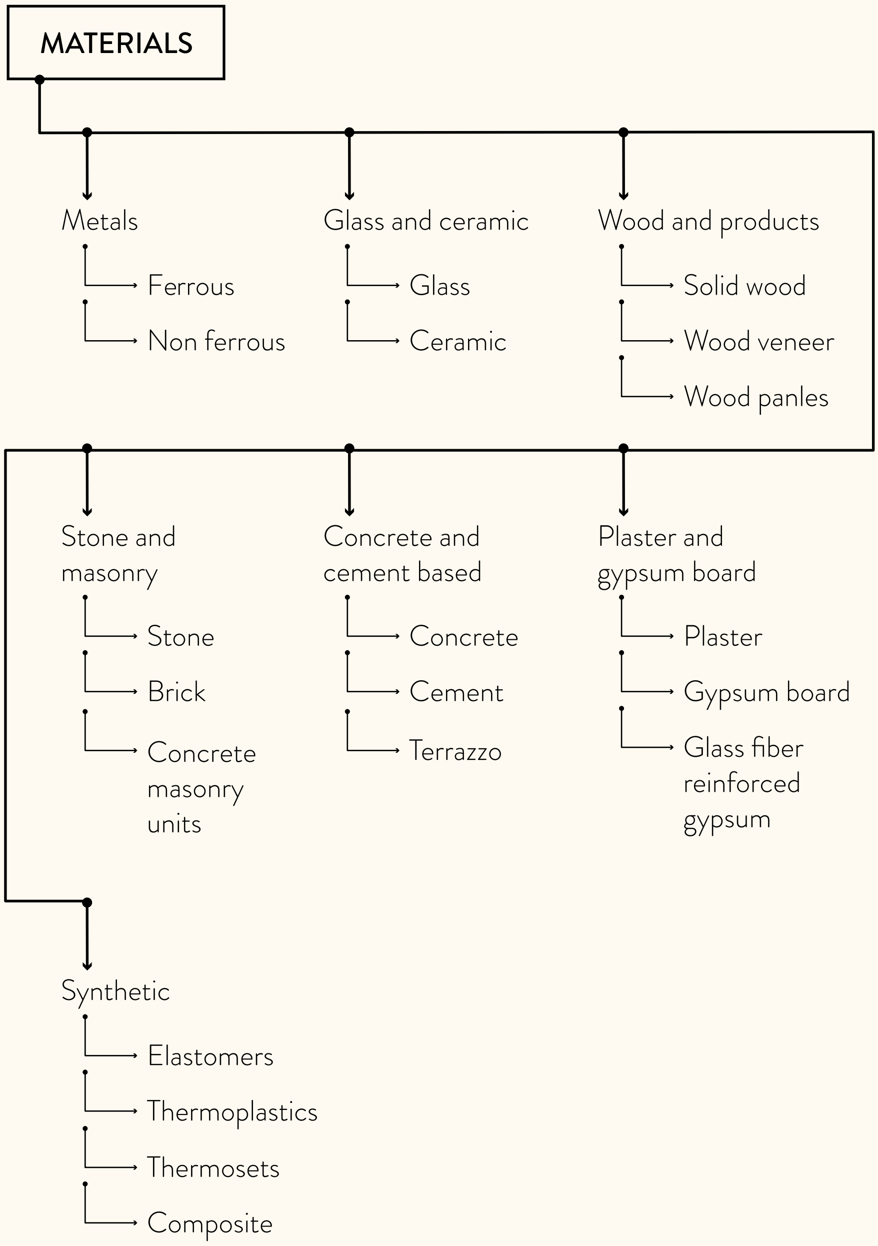
Note

Petrovic division of materials in grown, extracted and made is quite unconventional and, despite providing a more environmentally focused approach to the material world, it has some flaws. This organisation might indeed not be very helpful in when considering materials properties or applications, presents overlaps between categories, especially when considering composite materials, and does not work well when taking into account products. Nevertheless, it could help designers in having a better understanding of where materials come from.

Source: from Petrovic, E., Vale, B., & Zari, M. (2017). Materials for a healthy, ecological and sustainable built environ - ment (1st ed.) Woodhead Publishing.

Figure 2.7

Materials classification by Binggeli C. in Materials for Interior Environments.



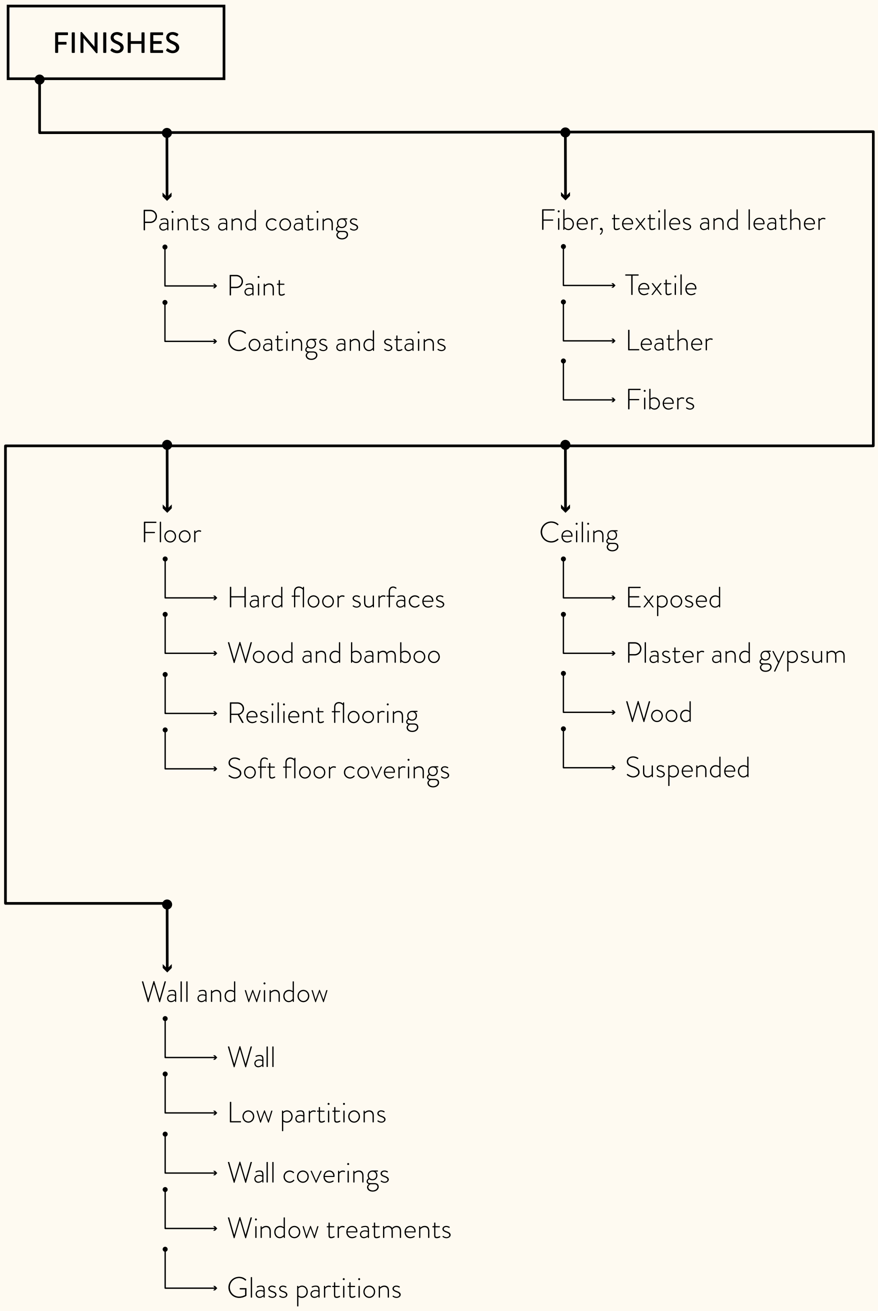
Note

Binggeli's classification, being divided into materials and finishes, is more complete and comprehensive than Godsey's. This categorization indeed introduces a separation that is quite relevant in the practice of interior design and enables users to have a wider view of the elements of an interior. However, browsing this classification can still be confusing since finishes are organised both by "material" and by "technical element" (e.g. ceiling, floor).

Source: from Binggeli, C. (2014). Materials for interior environments. (2nd ed ed.). Hoboken, New Jersey: John Wiley & Sons.

Figure 2.8

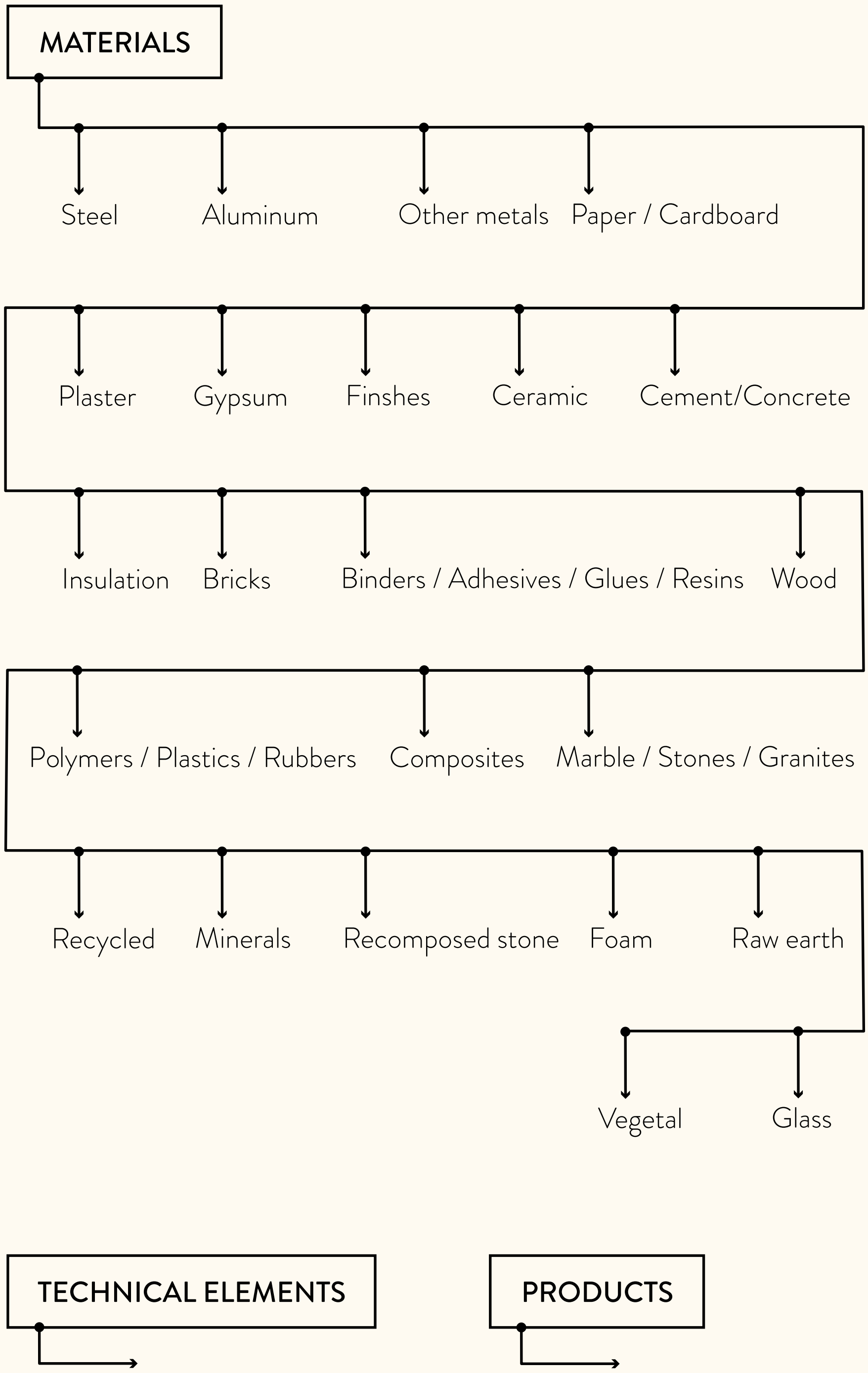
Finishes classification by Binggeli C. in Materials for Interior Environments.



Source: from Binggeli, C. (2014). Materials for interior environments. (2nd ed ed.). Ho - boken, New Jersey: John Wiley & Sons.

Figure 2.9

Materials classification from ArTec, IUAV Material library



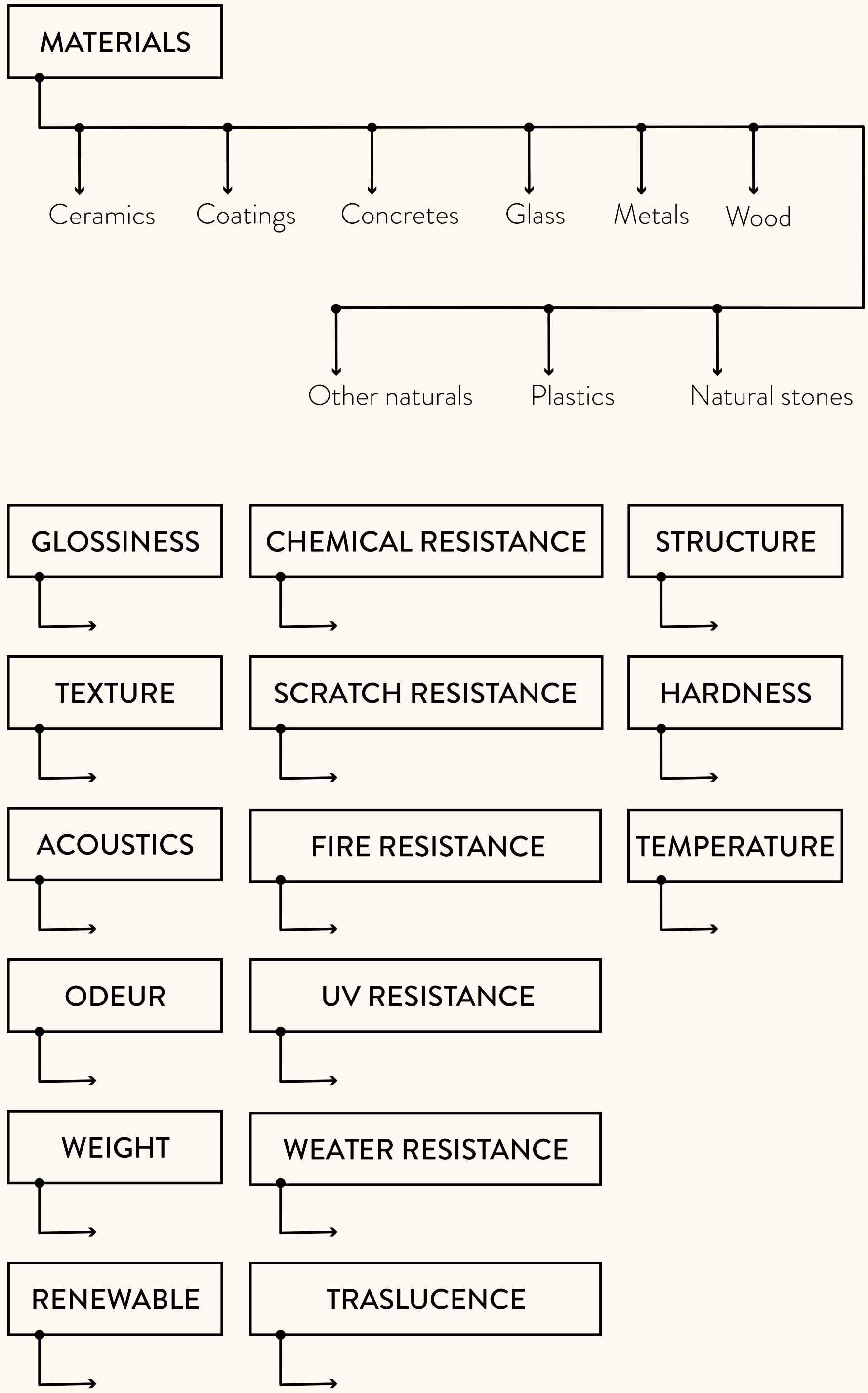
Source: from IUAV. (2020). ArTec. Retrieved 09/29, 2020, from http://materioteca.iuav.it/

Note

ArTec database by IUAV (University Institute of Architecture of Venice) is the online tool that allows the research and use of information relating to materials, products and systems contained in the physical archive. It has been designed to allow students to carry out a targeted research and it has therefore been structured with two search options. Users can consult the library by choosing the material or the desired technical element. The subdivision by technical element circumscribes the field of investigation to the constituent parts of the building (e.g. roofs, closures, partitions, etc.), while the subdivision by material directly identifies the material of which the product / technical element is made (e.g. wood, steel, concrete, etc.). Moreover, at each material and technical element are associated a series of products (IUAV,2020).

Figure 2.10

Materials classification from Material District



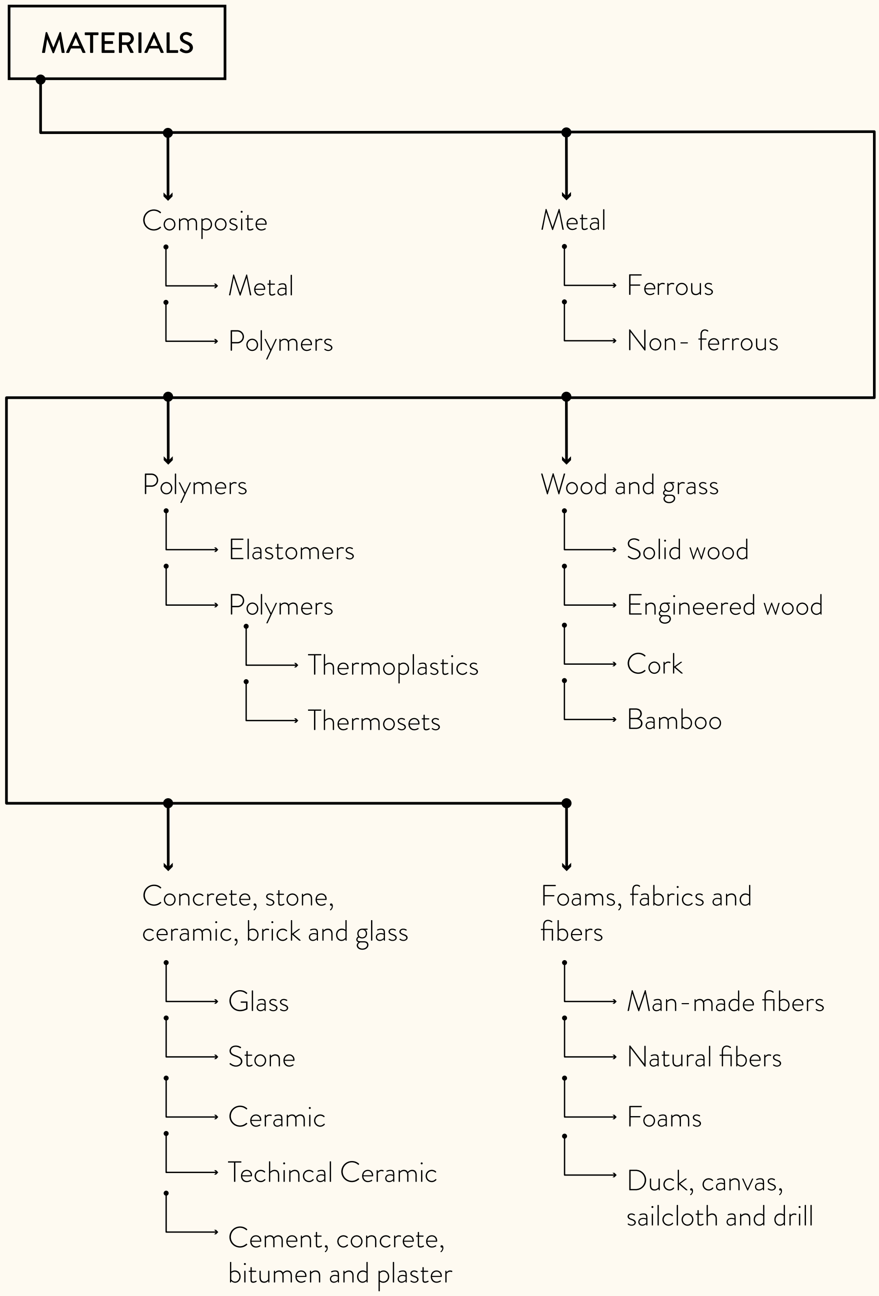
Source: from Material District. (2020). Retrieved 29/09, 2020, from https://materialdistrict.com/

Note

Material District claim to be the world's leading match-making platform in the field of innovative materials. It's database is indeed very rich and well organised. The material classification is very simple but several are the parameters that can be used to browse the library. The parameters refer to the materials characteristics and properties (Material District, 2020).

Figure 2.11

Materials classification from CES - interior materials



Source: from Granta Design Limited. (2020). CES EduPack software. Cambridge

Note

CES EduPack materials database is divided in levels. The Architecture level presents 4 sub-levels: enclosure, interiors, services, superstructure. Since this work focus is interior environments, it has been decided to take into account the materials under the interior level. This categorization includes only materials used in interior environments and seems to organize them according to their physical properties. It is useful to follow it to describe material's mechanical and physical properties but not very helpful or inspiring when designing a space.

All these classifications have pros and cons. Godsey's mixes materials and products, making it easier to understand how materials are used but also confusing. What is the difference between one and the other? Binggeli's, being divided into materials and finishes, and including technical elements, can be even more confusing but introduces a separation that is quite relevant in the practice of interior design. Indeed, it would be appropriate to discern between materials that provide structure, those that act as a finish and finishes themselves. Finishing material consists of every material applied, attached, or adhered to a building substrate or structural assembly (wall, floor, or ceiling) to provide a finish or characteristic not inherent with the building substrate or structural assembly, while finishes are textures, colours, patterns, or a combination thereof, applied to a building material or finish material. Building materials are every material not considered a finish material and used as a support (Geren, 2010). IUAV classification does not provide this information but clarifies the link between materials, products and technical elements (figure 3.11), which was not evident in the previous divisions. This arrangement is thus very helpful when working on a project because it gives the chance to find products for a specific use. Also, CES is strongly related to the world of interior design and architecture but it only helps in understanding what materials are used in these fields and not how and where.

Nevertheless, all the previously mentioned categorizations, concerning mainly one field, do not foster innovation. Material District instead, not grouping materials according to their use and allowing users to look for properties and characteristics, favours the breaking of some material "stereotypes" and new discoveries. Who said wood can't be transparent or concrete be lightweight? This is also amplified by linking materials to keywords (e.g. sustainability, smart materials, sense and sensibility), that permits users to find materials that are not related because of their properties or physical characteristics but for other reasons.

As we have seen, materials can be classified variously, although they always have the same set of attributes and environmental impacts. The following section will provide the main ecological impacts and features of some materials.

2.3.2 Materials environmental impacts

Materials are characterised by properties and transformation processes but, as mentioned in the previous chapter, also by their impacts on the environment. Materials impacts on the environment can be described as the consequences provoked by obtaining, processing, using, and finally disposing of materials. They thus occur in every life phase of the material.

To give an overview of materials environmental impacts, the materials' classification showed in figure 2.6 will be used as a reference. Petrovic's (2017) division of materials in grown, extracted, and made presents some shortcoming but allows to have a more sustainably centred take on materials.

Figure 2.12

Mining machine in Kosova

GROWN

Materials that are grown include timber, straw, bamboo, but also fungi, algae and other plant-based and animal products. Grown materials are often renewable, meaning that are made of natural resources that can be replenished generation after generation, but this doesn't mean that they do not have environmental impacts. These depend on where materials come from, how they have been grown and in what specific context in order to consider impacts on ecosystem services. Indeed, ecosystem services, and more specifically the health of the soil, can be negatively affected by the addition of chemicals such as fertilizers, pesticides, and herbicides (Petrovic, 2017). Moreover, plants need land to grow and if that land is growing building materials it cannot generally also be used to grow food, energy, or be left as habitat for fauna and flora.

- The most used grown material is wood. Wood and other materials such as bamboo and cork are natural composite materials made of cellulose fibres embedded in lignin. Its properties depend on the specie and how and where it was grown but in general it can be said that wood is strong and stiff, it is a good thermal and electrical insulator and has good acoustical properties (Del Curto et alt., 2015). Wood is a renewable natural resource that typically has quite low levels of embodied energy [5] and whose use sequestrate CO_2 from the atmosphere. However, overharvesting wood can affect erosion, carbon dioxide absorption, oxygen generation and can damage natural habitats and biodiversity (Jones, 2008). These vary depending on the species of trees, the type of logging, the size of the operation, its location, whether the forest was old growth or plantation grown and how it was managed. Moreover, composite and engineered wood products have higher embodied energy levels and are more difficult to repurpose or cascade.
- Grasses such as straw, reeds, bamboo, hemp and vines have been greatly used in the past for building purposes because of their low costs and ease of manageability. Today, one of the most common grasses is bamboo because of the short time it takes from planting to maturity (5-7 years). For this reason, bamboo has almost been given the status of a sustainable silver bullet. However, one of the main issues with bamboo and other grasses is mono cropping. When a land is cropped for bamboo, and no other plants, it is unavailable for other uses, such as food growing, or as natural habitat. This is one of the problem with the so-called natural materials, that they can be considered sustainable when they are harvested to satisfy local demands but their sustainability becomes questionable when their production is "industrialized" (Petrovic, 2017).

Overall, the most important issues to be aware of with grown materials include impacts on soil health and nutrient cycling, interaction with the carbon cycle[6], and implications for biodiversity of plantation growing (Petrovic, 2017).

Note

[5] Embodied energy is all the energy associated with the life of a material, from extraction to end of life. It can be calculated per unit of mass (kg) or unit of volume but the most accurate calculation is done per unit of function.

[6] The continuous movement of carbon between different living organisms on earth and between living organisms and the environment, through natural processes like photosynthesis, respiration, and decomposition in the soil, and also the burn-ing of fossil fuels (Cambridge Dictionary, n.d).

EXTRACTED

Materials that are extracted or mined are those which most typically are dug out of the earth as raw materials and which are then minimally processed into various products. Most extracted materials are not renewable but many are abundant, such as earth and sand.
Some of the most common extracted materials used in interiors are stone, cement, concrete, plaster and ceramic.

- Stone has long been valued as a building material because of its strength, durability and thermal mass. Natural stone ecological impacts varies depending on the type of quarry operation, its size, and its location. Quarrying, transporting and manufacturing stone generally require a significant amount of water and energy. Moreover, quarrying rock removes vegetation and soil and generates dust and noise. The resulting holes may speed up erosion and damage the water supply (Binggeli, 2014). Stones are very durable and can therefore be repurposed and reused multiple times.
- Concrete is an artificial stone-like material made by mixing cement and aggregates with enough water to cause the cement to set, binding the entire mass. Concrete is mainly made of three components: rock and/or gravel (the course aggregate) + sand (the fine aggregate) + hydrated Portland cement. Concrete properties depend on several factors, but in general it is known its high strength and good insulating capacity. On the other hand, concrete has low tensile strength, is brittle and is susceptible to sulphate and acid attacks. Concrete is a generally safe and inert (does not off-gas toxic vapours) material, whose raw materials are widely available in large quantities. However, concrete is made of cement and cement consumes a considerable amount of water and energy, accounting for about 92% of concrete's embodied energy (despite constituting only 12% circa of the materials in concrete) (Binggeli, 2014).
- Plaster is composed of gypsum or lime with water, sand and sometimes glass or hair fibres. Its levels of embodied energy(2,09 - 2,31 MJ/kg, (CES, 2020))are about half that of cement (5,4 - 6 MJ/kg)but, like any other extracted material, its mining is environmentally damaging (Petrovic, 2017).
- Ceramics cover a wide range of materials that are neither organic nor metallic, with a great variety of electrical and thermal properties. Generally, they are hard, porous, brittle, resistant to corrosion and good electrical insulators. Ceramic materials are readily available and can be gained through low-impact mining but their processing requires high temperatures, thus they contain relatively high levels of embodied energy. Nevertheless, ceramics are very durable and can be reused and recycled.
- Metals are in general opaque, lustrous elements that are good conductors of heat and electricity. They are denser and heavier than other materials but also ductile and malleable. They typically tend to be stiff, strong, tough but their mechanical properties can vary greatly (Ashby, 2012;

Brostow, 2017). The mining and processing of metals create significant environmental impacts, including soil erosion, the formation of sinkholes, contamination of groundwater, and loss of biodiversity. Ore refinement processes produce heat, combustion emissions and consume a great amount of water, and metals manufacturing processes require agreat amount of energy and dangerous pollutants (Binggeli, 2014; Jones, 2008). Moreover, products containing metals, when thrown in landfills, often leak potentially harmful metals into underground water supplies. None the less, metals are durable materials that can be recycled efficiently and easily (when not alloyed) using far less energy than the one required for primary production (Jones, 2008).

- Glass is a hard, brittle substance made by melting silica with other materials such as soda ash and limestone at very high temperatures. Glass is considered part of the ceramics family and it is mainly valued for its optical properties but also for its high resistance to corrosion and good acoustic properties (Binggeli, 2014). The basic material for most glasses is sand, which is readily accessible and non-polluting. Melting and refining glass requires high temperatures, making its level of embodied energy quite high but recycling is possible and it requires less energy and produces fewer emissions. (Binggeli, 2014).

Broadly, it can be said that one of the main concern related to these materials is localized habitat damage. When investigating extracted or mined materials for use in buildings, it is important to know specifically where materials come from and what are the specific methods of the extraction and processing because they affect local habitat, biodiversity, interaction with the water cycle and associated GHG emissions and embodied energy estimates (Petrovic, 2017).

MADE

Materials that are made. Almost all building materials are processed to some degree however, some do not exist in nature and must be created by humans through complex and often energy-intensive processes. Common building materials that are made, according to Petrovic (2017), include glass, steel, plastics, and a large range of composite materials. Typical issues associated with made or highly processed materials include high embodied energy figures, non-renewability of raw materials, undesirable emissions to air, water, and soil, and rcyclability (Petrovic, 2017).

- Polymers encompass natural occurring materials as well as synthetic or semi-synthetic ones. They can be soft or hard, rigid or elastic, brittle or deformable, insulators or conductors, swelling or water repellent. Moreover, they are available with many levels of transparency and translucency, and in a great variety of colours. Polymers have a wide range of properties but they are mainly valued for their durability, and flexibility of form. Synthetic polymers are derived from petrochemical made from petroleum and natural gas. This makes them very stable but at the same time difficult to destroy and dispose of (Binggeli, 2014). Plastics are omnipresent materials in interiors and most of them are made from petrochemicals. Synthetic polymers deplete finite resources such as oil and natural gas, have high levels of embodied energy and their production can lead to emissions that promote global climate change. Moreover, they produce long-lasting wastes that degrade the environment. Indeed, synthetic plastics do not breaks down easily unless they are recycled or incinerated and therefore can last for hundreds of years and pollute both the land and the marine environment, resulting in a wide range of environmental and human health problems. Recycling is technically feasible for many polymers, but there are logistical problems associated with the collection and separation of the product. Furthermore, when plastics are mixed with other materials in building and interior products, they are more difficult to separate and recycle. On the other hand, plastics require much less energy for processing then metals do, are lightweight, reducing energy required for transportation, durable, and require little maintenance (Binggeli, 2014). A small but growing number of plastics for use in the building industry are made of plant-based (e.g. CA, cellulose polymers) or other starches and have an ability to be partially biodegradable. Despite this can make them less impactful in terms of end-of-life pollution, some, like CA, still have high impacts in other life phases (figures 2.14, 2.15).

- Composites can be defined as a combination of two or more dissimilar materials. Because composites are composed of dissimilar materials, they possess a profile of properties different from the individual components used to make them. The characteristic properties of each constituent interact, resulting in the collective behaviour of the composite. They can be made of a matrix and a dispersed phase, or they can be laminar. Laminates consist in the layering of different materials, while matrices composites consist of a continuous material called matrix encloses particles, fibres, whiskers or flakes, that constitute the dispersed phase (Brostow, 2017).
- Composites environmental impacts differ greatly according to the materials they are made of so an overall statement regarding them cannot be made. Since they cannot be recycled they must be repurposed and/or remanufactures at the end of their life cycle but they generally have longer life spans compared to the other materials.

As for extracted materials, when examining processed or made materials it is important to know specifically where materials come from due to what the local impacts might be, but also because of the differences between environmental laws and regulation in different parts of the world. In addition, designers should be aware of the impacts on local habitat and biodiversity, the interaction with the water cycle and marine systems, the associated GHG and other toxic emissions, and embodied energy estimates (Petrovic, 2017).

2.3.3 Impact Indicators

Ore, feedstock, and energy are drawn from the planet's natural resources and processed to produce materials. *How much the extraction of a material damages the local ecosystems?* Then, these are further processed to create the materials that are subsequently manufactured into products, which are distributed, sold, and used. *How much energy that material requires to be manufactured and how much GHG are emitted in the process?* Products have a useful life at the end of which they are discarded; a fraction of the materials they contain might enter a recycling loop, the rest is committed to incineration or landfill. *How its disposal will affect soil, water and air?*

It is now clear how materials impacts on the environment occur in all their life phases. To analyse a material life cycle it is useful to make a life-cycle assessment (LCA). LCA is a systems approach that traces the progression of a material, from ores to end of life, documenting the resources consumed and the emissions excreted during each phase of life. The output can be considered a biography, documenting where the material has been, what it has done, and the consequences of this on its surroundings (Ashby, 2013). The latter can be evaluated through a series of parameters or impacts categories that can differ according to the purpose of the assessment and field of interest. Some of the categories used in the construction sector LCAs include environmental impact, input flows and output flows waste, which are all described by different indicators.

ENVIRONMENTAL IMPACT

The environmental impact category delineates the potential effects on humans and the environment and include indicators such as global warming potential (GWP), that is a relative measure of how much heat a greenhouse gas traps in the atmosphere and measures the potential change in global or regional climate patterns (Ashby, 2013), and depletion of abiotic resources (ADP), that consists in the consumption of a resource faster than it can be replenished (Ashby, 2013). Other important eco-properties are also ozone depletion (ODP), acidification of soil and water (AP), eutrophication[7] (EP), photochemical ozone creation (POCP), eco-toxicity, human toxicity, water and air pollution.

The Qartz Common Products Database (QUARTZ, 2019) provide a list of 102 common building products, each defined by some of the previously mentioned eco-properties in two life stages: from cradle to gate[8] and end of life treatments. Figure 2.13, 2.14, and 2.15 show how some materials used in interiors rank in global warming potential, eutrophication and acidification of soil and water for the cradle to gate phase.

Note

[7] EP is the over-enrichment of a body of water with nutrients-phosphates, nitrates resulting in excessive growth of organisms and depletion of oxygen concentration (Ashby, 2013). The outcome is generally a loss in biodiversity.

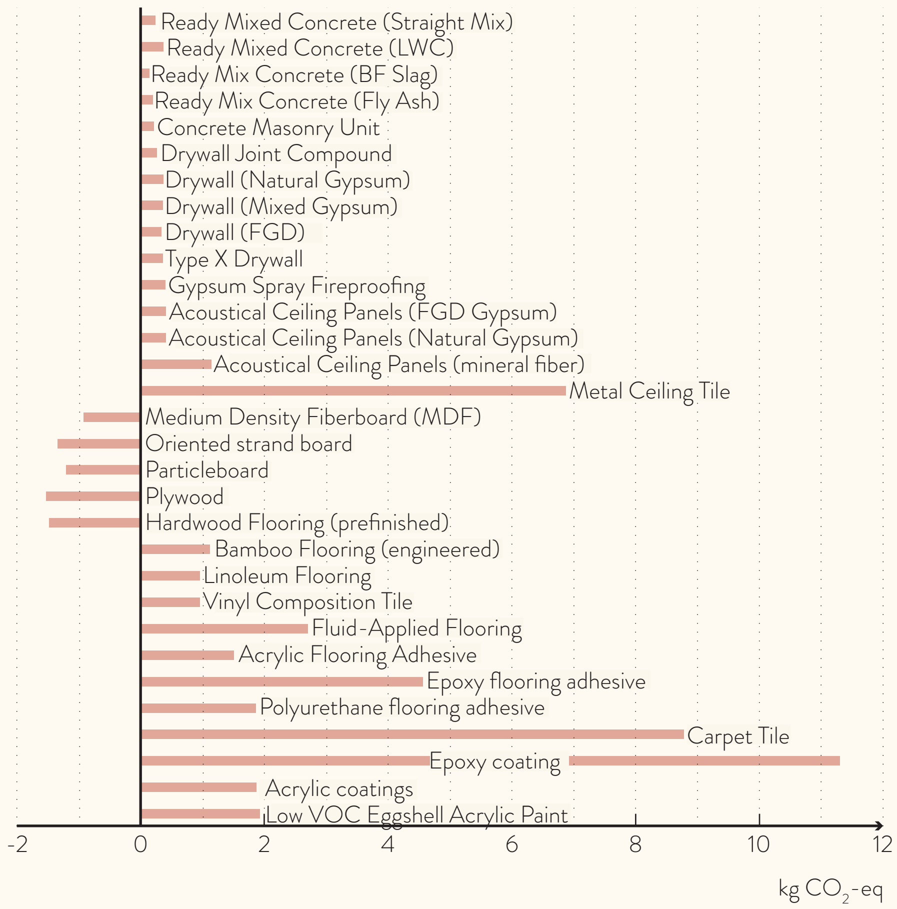
[8] From resource extraction to factory gate.

The data provided by Quartz (QUARTZ, 2019) cover only few specific materials therefore, in order to have a more uniform and comprehensive data set, that would allow to do some comparison, it has been decided to look at the materials and environmental categories present in the Cambridge Engineering Selector (CES). The software does not provide information regarding the GWP, EU, and AP, but gives some information regarding, carbon footprint, embodied energy and water usage of the primary production. Figure from 2.16 to 2.20 all refer to data obtained from CES.

Figure 2.13 shows GWP (from cradle to gate) of 31 materials and products used in interiors. GWP is measured in CO_2 equivalents, which means that other heat-trapping gases such as methane or nitrous oxide are expressed in terms of the amount of CO_2 that would create the same amount of warming. Wood products have negative values of GWP since they store CO_2.

Figure 2.13

Global warming potential of 31 materials and products used in interiors (cradle to gate)

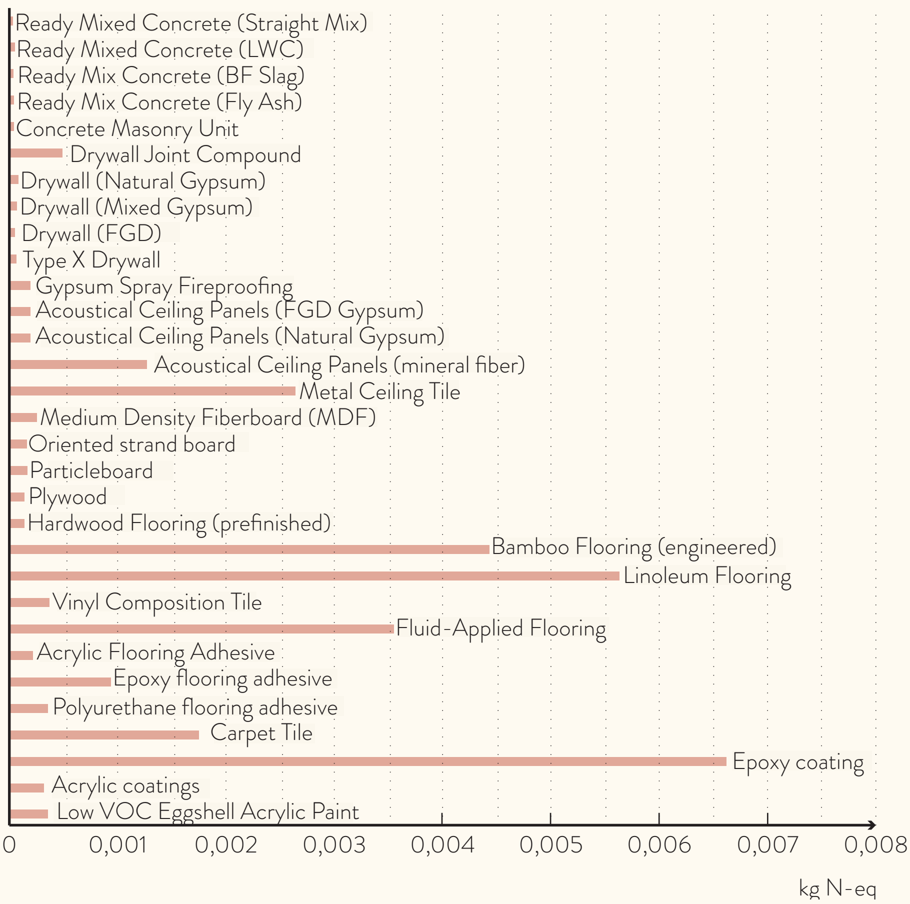


Source: from QUARTZ. (2019). Quartz common products database.

Figure 2.14 shows eutrophication levels of the same materials of figure 2.13. Eutrophication covers all potential impacts of excessively high levels of macronutrients, the most important of which are nitrogen (N) and phosphorus (P). Nutrient enrichment may cause an undesirable shift in species composition and elevated biomass production in both aquatic and terrestrial ecosystems. In aquatic ecosystems, increased biomass production may lead to depressed oxygen levels because of the additional consumption of oxygen in biomass decomposition.

Figure 2.14

Eutrophication potential of 31 materials and products used in interiors (cradle to gate)



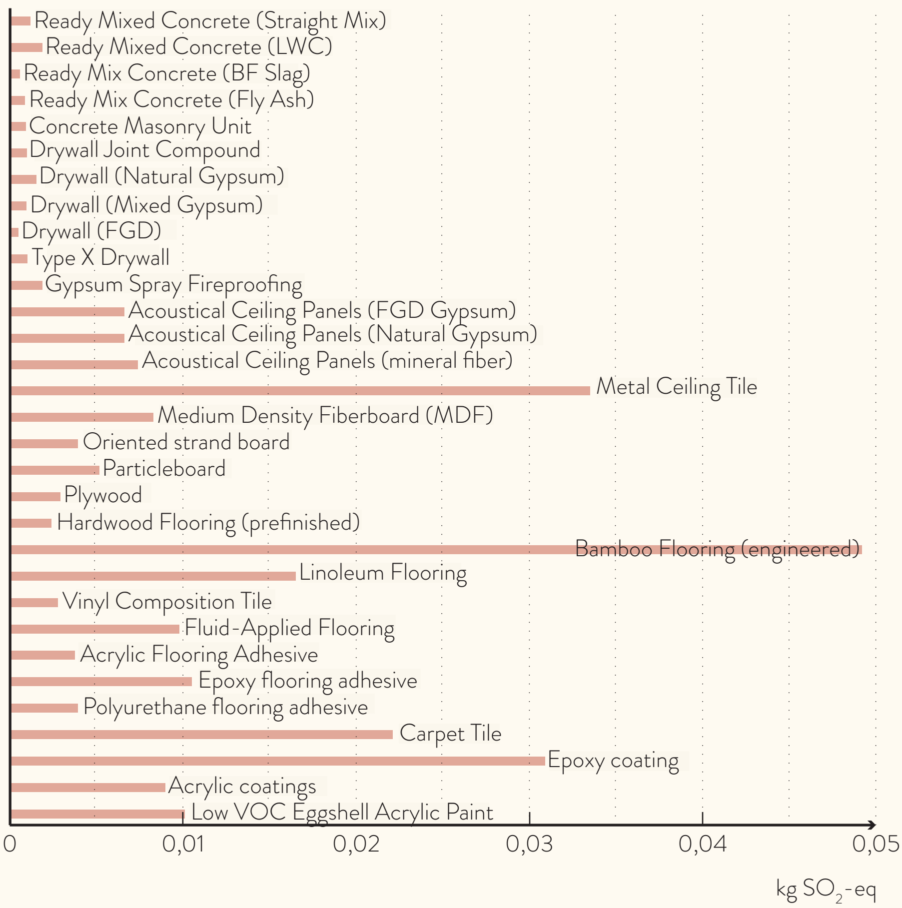
Note: from QUARTZ. (2019). Quartz common products database.

Figure 2.15 shows acidification. Materials can cause acidifying effects to the environment. The acidification potential is a measure of a molecule's capacity to increase the hydrogen ion (H+) concentration in the presence of water, thus decreasing the pH value. Potential effects include fish mortality, forest decline, and the deterioration of building materials.

Figure 2.16 features data from CES and display the carbon footprint of a series of materials and products.

Figure 2.15

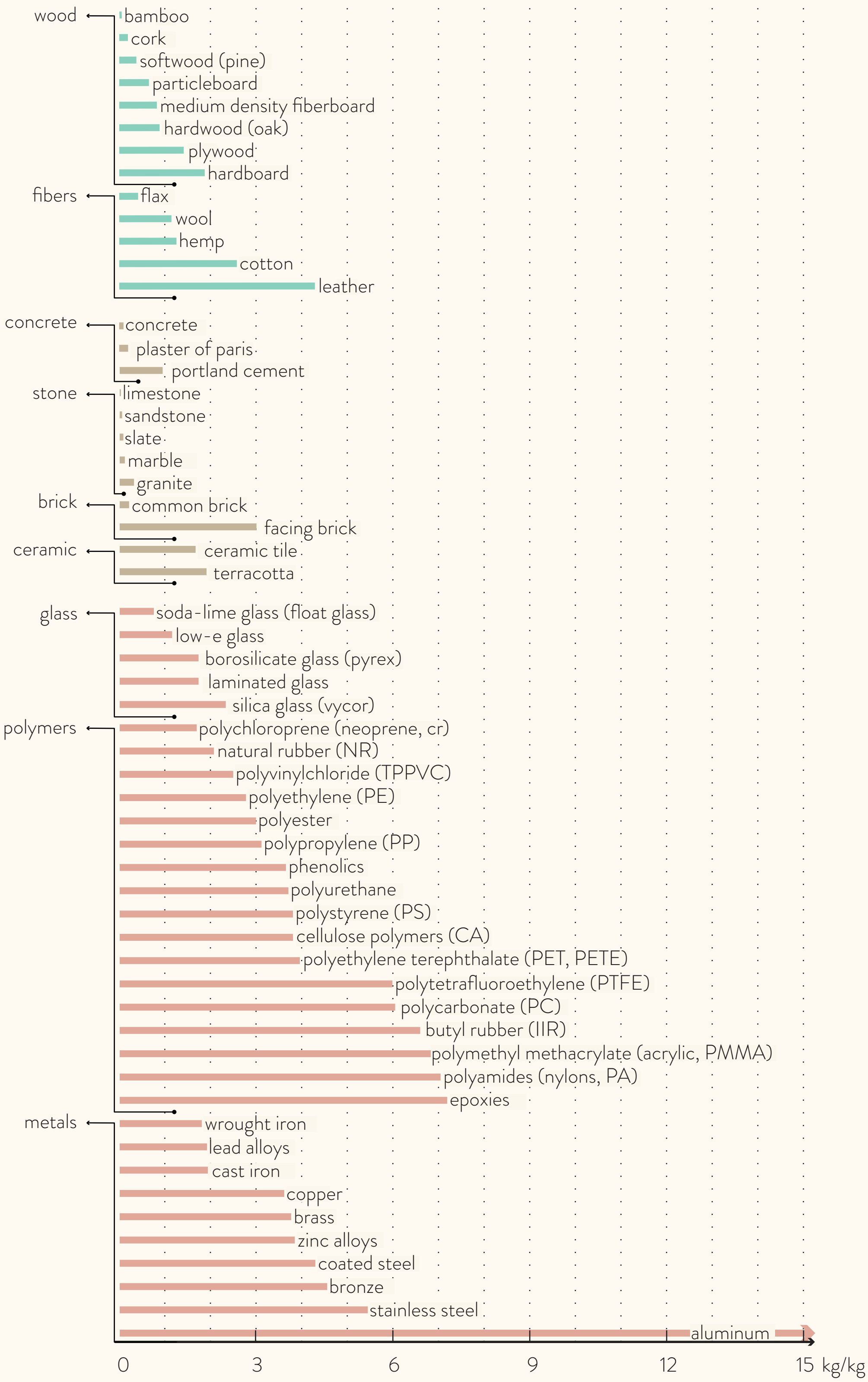
Acidification potential of 31 materials and products used in interiors (cradle to gate)



Note: from QUARTZ. (2019). Quartz common products database.

Figure 2.16

Materials and products' CO_2 footprint (kg/kg) for primary production



Source: Granta Design Limited. (2020). CES EduPack software. Cambridge

INPUT FLOWS

The indicators describing input flows are instead related with the types of resources and energy used and focus on weather a renewable or non-renewable energy resource has been used and for which purpose.

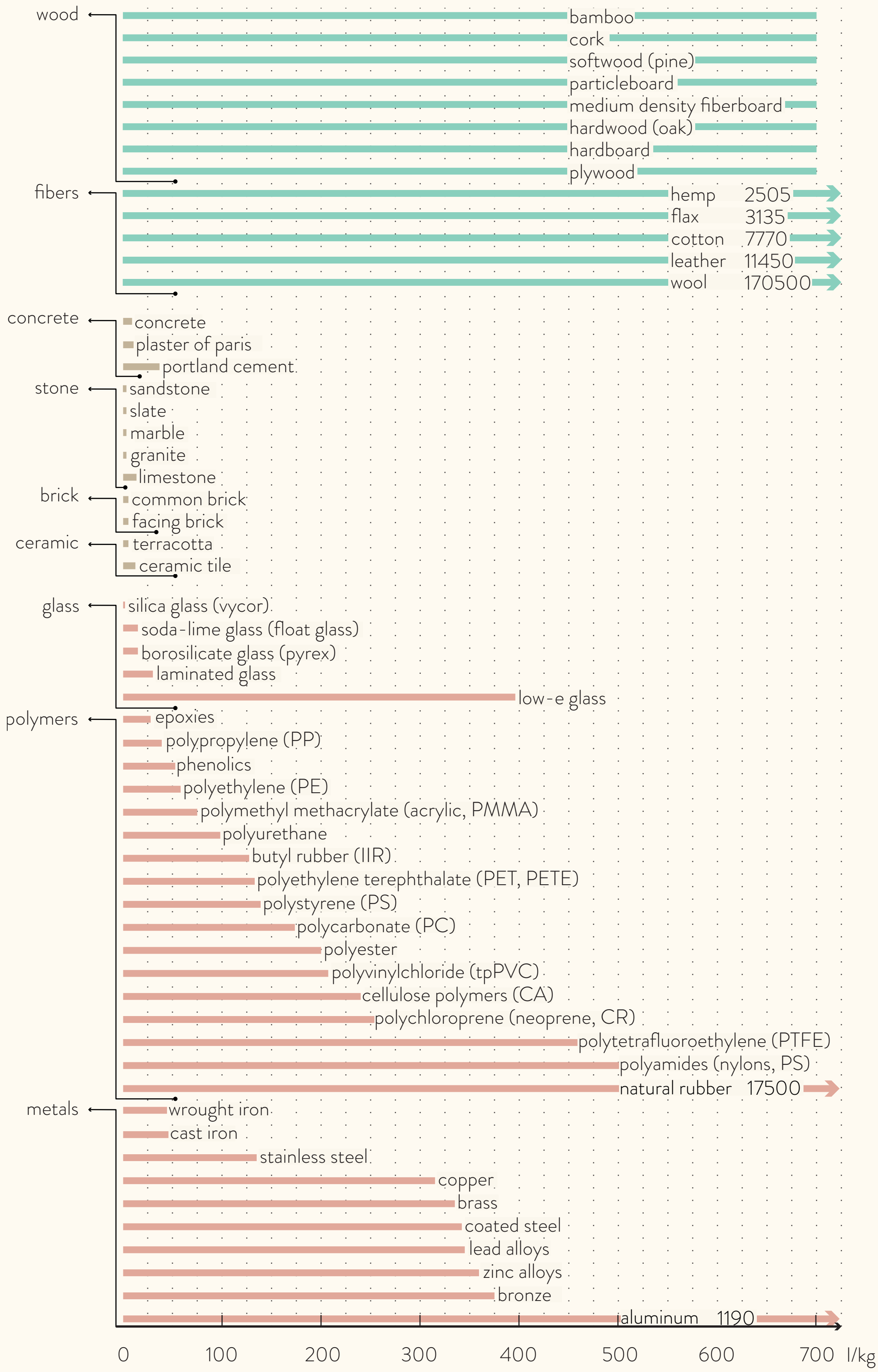
Between the resources used to produce a material there is water, which is used in many stages of a material's life cycle. The amount of water needed to produce a material depends greatly on the material in question. In general, grown materials are more likely to require greater amount of water in the primary production phase but less in the processing phase, while this is in reverse for made materials.
From figure 2.17 emerges that using grown materials and products consumes more water than employing made ones. However, it should be remembered that most grown materials, if grown in the proper habitat, do not need to be actually watered but will simply live and flourish thanks to the natural precipitations. For example, growing a pine tree in Finland will surely require a lot of water but most, if not all of it, will be naturally provided by the environment, without the need for diverging streams of water or employing systems to water the tree. The same cannot be said for metals or polymers.

Water is a fundamental resource but, as explained before, the most relevant resource related to material production is energy. To evaluate energy, one of the parameters used is the embodied energy indicator. Figure 2.18 and 2.19 show levels of embodied energy for the same materials but taking into account different basis of comparison. One calculates embodied energy per unit mass while the other per unit of volume.
The two graphs (2.18and 2.19) show very different results for some materials (especially polymers). So what basis of comparison should be used if we have the objective of minimizing the embodied energy of the materials used in a project? The best option is to calculate embodied energy per unit of function. The functional unit is a reference unit for the performance of a product and defines the service that needs to be delivered by that product. For example the functional unit for a paint is m^2 while the one of a ceramic tile is kg. CES does not give the opportunity to calculate EE for functional unit but other databases such as Environmental Performance in Construction (EPiC) do.

Despite the differences, by looking at the graphs it is clear how extracted materials have the lowest levels of embodied energy. Nevertheless, this shouldn't lead to the conclusion that materials like concrete and cement have low impacts on the environment. Indeed, despite their EE levels aren't high, the volume in which they are used is tremendous compared to other materials and they thus have very high impacts on the environment.

Figure 2.17

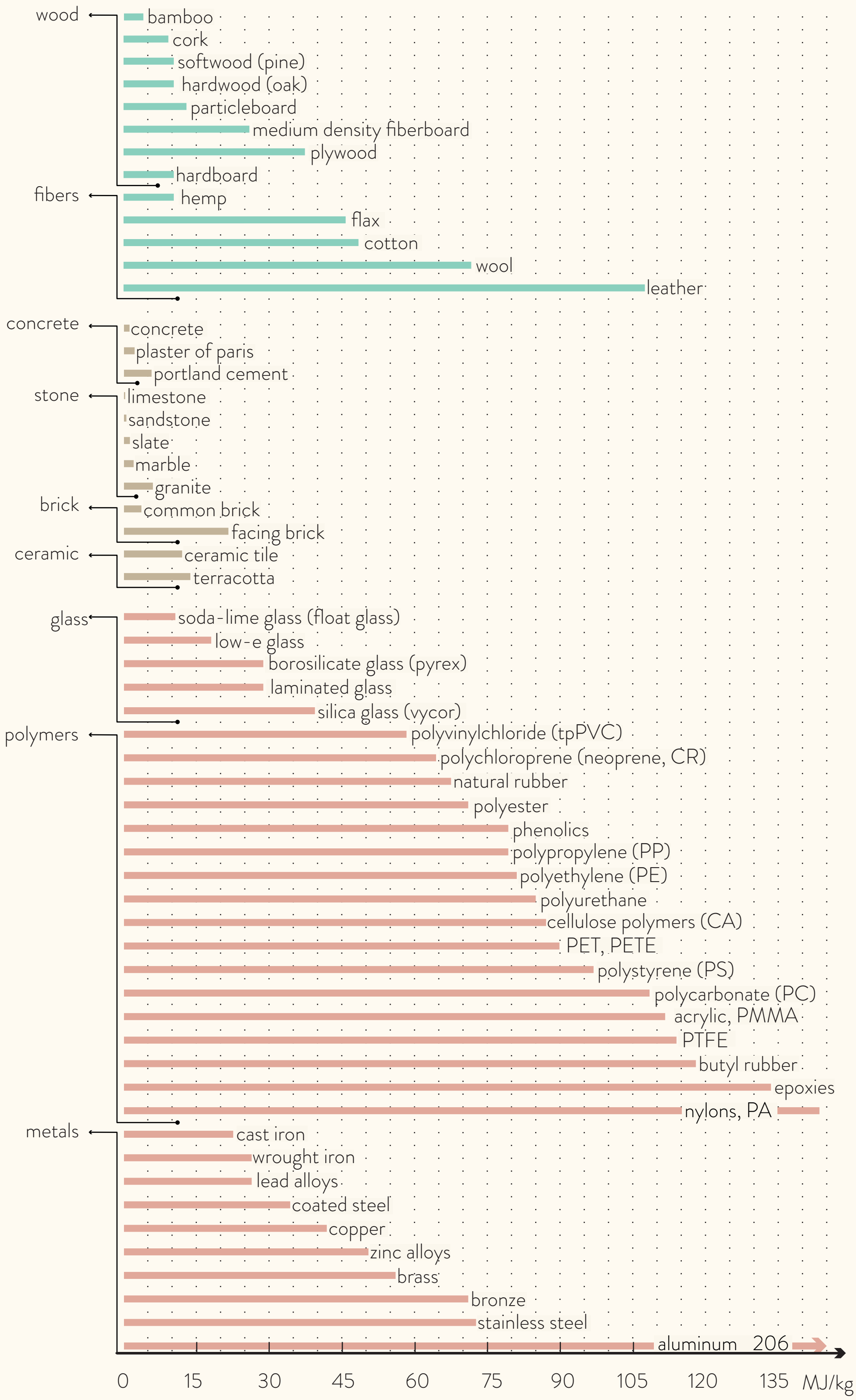
Materials and products' water usage for primary production (L/kg)



Source: Granta Design Limited. (2020). CES EduPack software. Cambridge

Figure 2.18

Materials and products' embodied energy for primary production (MJ/kg)



Source: Granta Design Limited. (2020). CES EduPack software. Cambridge

Figure 2.19

Materials and products' embodied energy for primary production (MJ/m³)

Source: Granta Design Limited. (2020). CES EduPack software. Cambridge

OUTPUT FLOWS

The category of output flows waste describes the waste streams and end of life options and features indicators such as components for reuse, materials for recycling, materials for energy recovery, energy production. As figure 2.20 shows, small percentages of materials (excluding metals) are reused or recycled. However, materials used by the construction industry have a major impact on waste and waste puts pressure on land use and triggers pollution, including emissions of greenhouse gases that cause climate change. Construction waste is caused by demolition of existing buildings and spaces, over-ordering of new materials for building sites, inefficient manufacturing processes, and failure to design to standard modules (Moxon, 2012).

Materials' end of life is too often forgotten in interior design project yet, considering that many projects have short life spans, it should be a major concern when selecting materials. Figure 2.21 shows the end of life possibilities of the interior materials of the QUARTZ database.

Another output stream frequently overlooked is packaging. Every material and product must arrive to the project site in perfect conditions and is thus carefully packed and protected. Besides, the amount of packaging material used could be reduced by designing smarter solutions and designers could choose products that require little protective packaging, and favour suppliers that commit to limiting packaging or offer recycling systems for their packaging (Moxon, 2012).

All these data gives valuable insights on materials consequences on the environment but while be said the engineering properties of materials are well characterized, these eco properties aren't. There are no sophisticated test machines to measure embodied energies or carbon footprints and many are the variables that lead to uncertainties. The differences in the processed by which materials are made, the differences in energy mix in electrical power in different countries, and the problems in assessing energy, CO_2, and the other eco-attributes all contribute to the imprecision (Ashby, 2012). This doesn't mean that those indicators shouldn't be considered or looked at but simply that other factors may play a critical role when selecting low impacts materials and evaluating their sustainability.

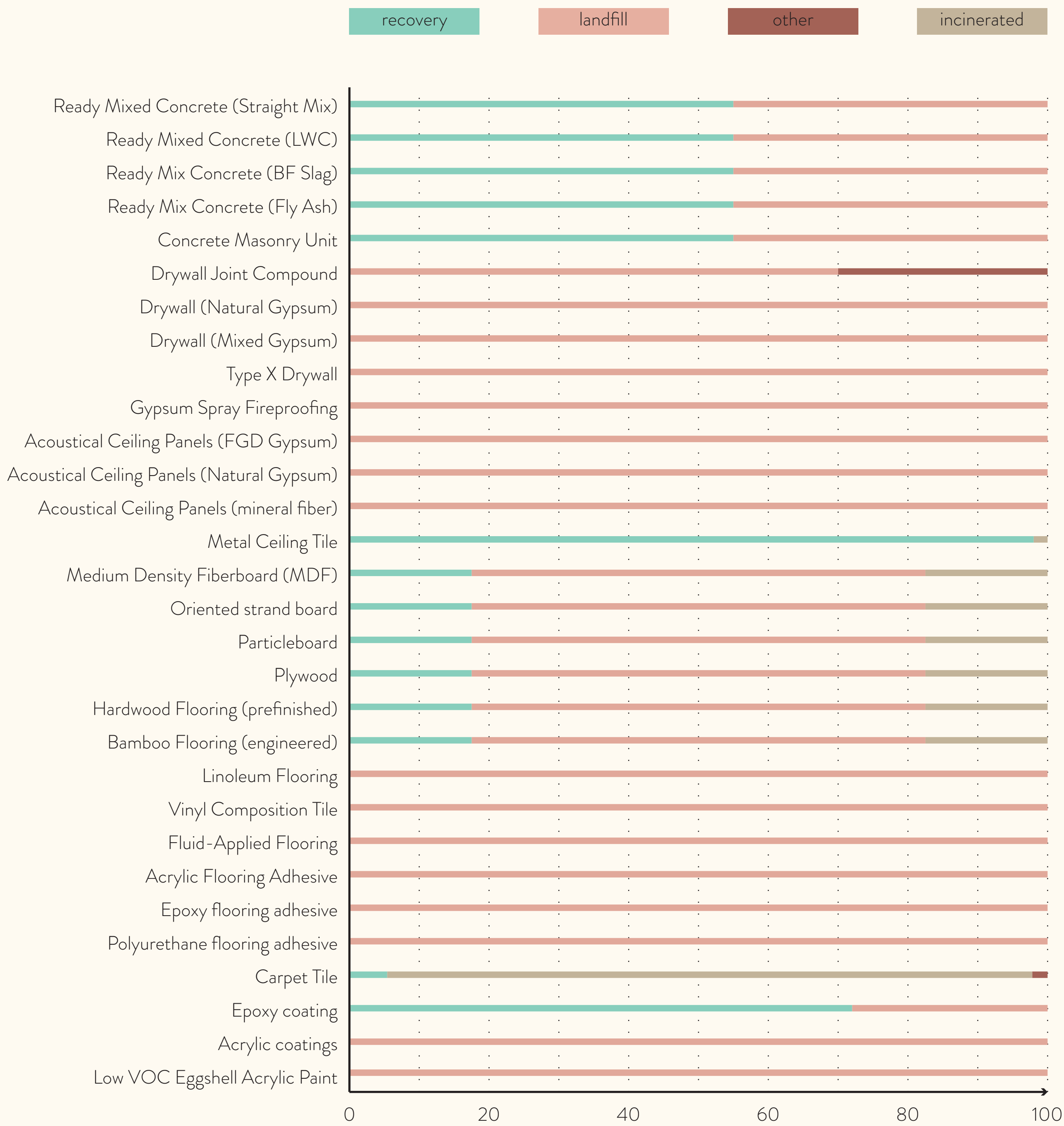
Figure 2.20

Materials and products' recycling and reusing fraction in current supply (%)

Source: Granta Design Limited. (2020). CES EduPack software. Cambridge

Figure 2.21

End of life treatment possibilities (percentage) of 31 materials and products used in interiors



Source: from QUARTZ. (2019). Quartz common products database.

3

Environmentally sustainable interior design

3.1 Environmentally sustainable interior design

In the previous chapter a description of what are environmental sustainability and interior design has been provided but how can we frame environmental sustainability in the practice of interior design?
Environmentally responsible interior design addresses both the health and the well-being of people in the built environment and the health and well-being of the global ecosystems that support life for current and future generations (Jones, 2008 p 86). It is a practice with a comprehensive perspective that seeks to minimize the negative environmental impact of the interior environment and at the same time create indoor spaces that are environmentally sustainable and healthy for the occupants (Pilatowicz, 1995).

Concerns regarding environmental sustainability already aroused in the fields of design and architecture in the 1970s with Buckminster Fuller teaching and work, but it is only very recently that it has become a central topic. In architecture, the question for sustainability has been explored, extensively regulated, and despite we are still far from achieving zero-emission buildings, many improvements have been made and good practices are catching on. Also in the design field, the issue has been approached, investigated and different design methods developed. The approaches ranged from those with a micro perspective, more focused on a redesign approach of the product itself (green design) or it's life cycle (eco-design) to those with a larger perspective focused on how to influence users behaviours (emotionally durable design) or how to transform products into services (sustainable product-service systems) (Design for sustainability, 2019). However, the question for environmentally sustainable interior designs, being on the borderline between the two fields, has still not gained much importance. One reason for this could also be the apparently smaller influence of interiors on the overall building sustainability. A major part is undoubtedly played by the structure of buildings, their systems and orientations, therefore, the interior designer's role on a project can seem small when design decisions with greater environmental consequences are beyond their scope (Moxon, 2012). Moreover, all building activity is environmentally damaging to some extent, and no building method or material is completely benign, hence it is impossible to practice interior design without causing any environmental damage (Moxon, 2012). Thus, even once an interior designer has committed to developing more sustainable solutions, he/she must acknowledge that it is rarely possible to create an entirely sustainable design.

Nevertheless, interior designers must accept these limitations and embrace the challenge of doing the best they can. There are indeed still many practices within the interior design practice itself that can lessen the devastating impacts on the global environment (Pilatowicz, 1995). These can include energy efficiency and conservation tactics through the appropriate choice of lighting systems, use of natural lights, choice of colours, materials and assembling methods, but also the promotion of recycling, use of recycled materials and recyclable materials and products. In this dissertation, much importance has been given to materials thus the following sections will focus on the main concerns that regard them: material selection, assemblies and the interior lifetime and life cycle.

Every one of these expedients involves addressing controversial issues, taking into account numerous factors and making intricate decisions. The complexity of the matter can be overwhelming, but rather than be discouraged, professionals should embrace compromise and accept that there is not always one perfect solution (Moxon, 2012). Interior designers should indeed seek a compromise between different sustainable measures and methods, weight up the pros and cons of every material, product or strategy to decide whether the positives outweigh the negatives. In some instances, this will be an objective decision; in others, it will depend on the designer's opinion of which environmental issues should be given the highest priority (Moxon, 2012, p.63). To be effective this process must be underpinned by in-depth knowledge of the environmental implications of using a particular material, system, or process. Once the consequences of these decisions have been fully understood, the interior designer can have confidence in his/her judgment as to how best to proceed (Moxon, 2012, p.70).

Being informed on the implications of the different options and being aware and updated on the broad agenda of sustainability allows designer not only to make responsible judgments but also to better interact with the client and the other professional figures present in the project. Indeed, on many projects, an interior designer will work within a large project team. As well as the client, end-user, and contractor, the interior designer may work alongside a range of consultants and organizations, including architects, engineers, estimators, project managers, local authorities, historical commissions, and suppliers. These diverse groups sometimes have conflicting agendas, and may not see sustainability as a high priority among other project considerations. It is paramount to be prepared for this and anticipate their potential objections to sustainable design choices (Moxon, 2012, p. 155)

The following sections (3.1.1, 3.1.2, 3.1.3) explores the material related considerations mentioned beforehand, while section 3.2 outline the strategies that can be applied in response to the considerations above.

3.1.1 Considering the life time and the life cycle

Considering the lifetime of a project is a fundamental aspect that should be considered in order to ensure an environmentally sustainable interior. Interiors have indeed a much shorter lifetime than buildings, and are way more subject to fashion and market changes, "needing" therefore to be refreshed and re-modelled more frequently. Besides, many interiors (e.g. retail, exhibitions, events settings) are intended to be short-lived, generating a significant quantity of waste if not designed with an appropriate life cycle in mind (Moxon, 2012). Knowing how long the completed interior is likely to remain in place empowers designers to choose materials, and building techniques that are suited to this period and allow them to plan accordingly for demolition, flexibility, or future adaptability (Moxon, 2012). It is not necessary to know exactly for how long the interior will last, simply whether it will be temporary or long-lasting. Temporary projects have very limited lifespans thus is not worth investing in complex, expensive, hard-wearing, or high-energy solutions. It would be better using materials that have a minimal environmental impact and can be repurposed or recycled. This also provides a great opportunity for designers to develop simple and clever solutions from sparse materials. Moreover, in this type of project is particularly important to choose and design how the materials are put together, in order to facilitate disassembly and recycling. These considerations are also relevant in long term projects, like an apartment or a house, but since these interiors will stay in place almost indefinitely, it is acceptable to use materials with higher environmental impact if their characteristics suit the project. In these cases, priority should be given to the durability of materials and their ease of cleaning and maintenance. Installing a stone floor in the entrance of a public building might look unsustainable when considering the consequences of extracting and transporting the material but this pays off when looking at its durability end ease of maintenance.

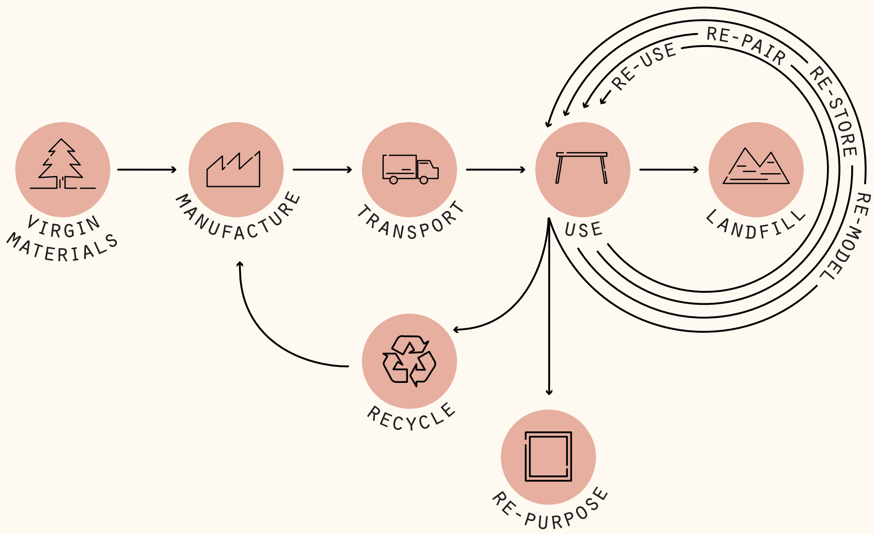
Designers must also consider the longevity of materials and be confident that the materials are durable, resilient, and maintainable with reasonable effort and cost to the users. Furthermore, when designing for longevity the interior designer must also consider how a material will change over time as a result of its function. A wooden floor will become worn and dented and stone steps will erode under abrasive feet. The way the material "wears" will give the space a sense of identity, enhancing the character of the interior, marking the passage of time, personal histories and experiences. (Brown, 2012).

These concerns highlight how only considering the lifetime is not satisfactory and the life cycle of a project should also be taken into account. The life cycle begins with demolishing any existing building or interior to make way for a new project, and continues after the design period, through the operation phase, to what happens after the new interior's demolition. A sustainable life cycle forms a genuine circle, with the demolished materials being reused or recycled to make new products for another interior. Unfortunately, many projects have a more linear life cycle, with much of the demolished material becoming landfill waste (Moxon, 2012, p.80) Needless to say, there are also environmental impacts throughout a project's life cycle, such as maintenance, that need to be considered. So the interior designer must both evaluate the effects of producing the interior - by understanding each product's journey from its raw materials to its installation - and think beyond this, considering how the space will be used and maintained, and what will happen at the end of its life (Moxon, 2012, p.80).

Looking at each stage of the life cycle helps the designer to see the bigger picture, recognize the long-term environmental impacts, and be empowered to make more sustainable design decisions (Moxon, 2012).

Figure 3.1

Graph representing a more sustainable lifecycle

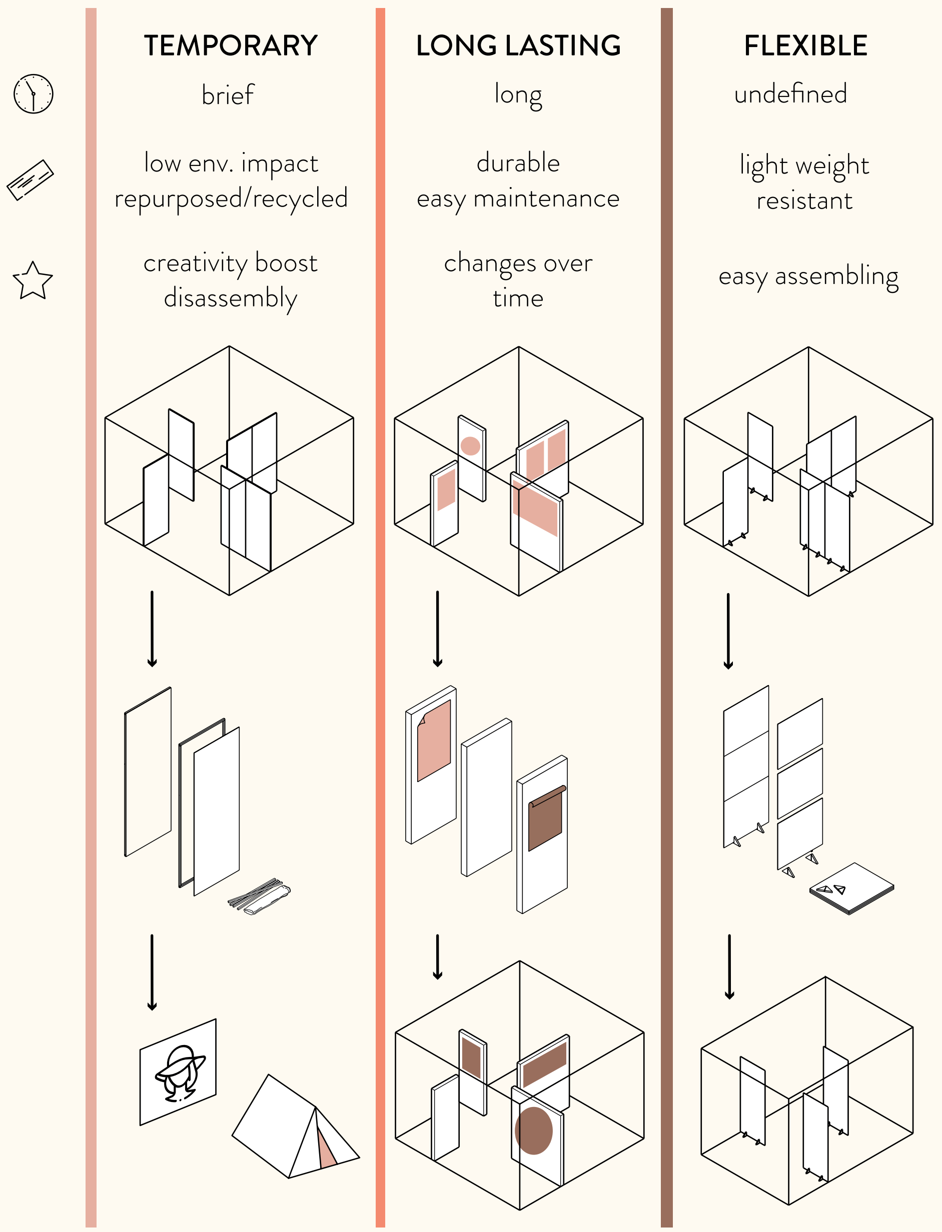


Each of the two project categories noted before (short and long term) have quite different requirements and implications but both can be flexible. A flexible project is one that needs to accommodate changes in layout or use, either being flexible enough to accommodate daily changes or adaptable to adjust to longer-term changes. The options for an exhibition project provide a good illustration of the varied requirements of the three project categories (figure 3.2).

An exhibition could be for a one-off show, required for perhaps one week and then never used again, and therefore a temporary project. Alternatively, it might be required to travel around the world, being repeatedly installed and dismantled for months or even years, and having inherent flexibility to adapt to different spaces. Conversely, it might be a permanent, static exhibition in a museum that would not need to change in the foreseeable future and must be built to last a long time. A different design approach is demanded for each of these scenarios to ensure a successful and sustainable project (Moxon, 2012, p 155).

Figure 3.2

Graph representing the link between time, design and materials



3.1.2 Selecting materials

As seen in chapter 2, materials constitute a prominent element of interiors and have various environmental impacts. Their selection is therefore critical but, as the possible materials and finishes used in interior environments are several, and encompass an immense, diverse and always changing body of knowledge, it is also very challenging. Hence, it is useful to use some strategies to make this process less bewildering.

Ashby (2012) defines the act of selection as the converting of a set of inputs, the design requirements, into a set of outputs, a list of viable materials and processes. The base requirements to carry out a solid material selection include an information structure (e.g. classification) that allows both simple and deep indexing and one or more selection methods. The main selection methods pointed out by Ashby are four: selection by analysis, by synthesis, by similarity, by inspiration.

- Selection by analysis works by deductive reasoning and is mostly used by technical engineers. It starts from listing the design requirements, or rather what a material should do. These are later translated into constraints, which are essential conditions that must be satisfied (e.g. a specific value of thermal conductivity value or fire resistance), and objectives that are a quantity for which a specific value is requested (e.g. cost, volume), so that they can be applied to a materials database (from "do" to properties). The database of materials and their properties is then screened. Those that fail to meet the constraints are eliminated while the ones that remain are ranked. This method is systematic, robust, based on a deep understanding of materials and precisely defined. This last provision, however, limits the approach to a subset of well-specified problems and well-established rules, preventing possible contaminations between fields (Ashby, 2012).

- Selection by synthesis is based on inductive reasoning and consist of drawing on past experience, seeking a match between the desired features, intentions, perception, or aesthetics (design requirements) and documented design solutions, stored in a database of product "cases." Since it depends on previous experiences and designs, it might not suggest radically new solutions, but it can also encourage cross-pollination between different sectors (Ashby, 2012).

- Selection by similarity works by seeking materials with selected attributes that match those of existing material, without knowing why these have the values they do but only that they are relevant for the success of the design A search for similar materials can serve as a method of expanding the set of possible material solutions and brake pre-conceptions, introducing creativity or novelty in a design solution. Indeed, pre-conceptions are often a shortcut to a quick solution and constrain innovation (Ashby, 2012).

- Selection by inspiration is accidental. In this methods ideas and solutions are found randomly by exploring different fields, interacting with new materials or simply by reading a magazine.

Each of the methods has its strengths and weaknesses and, some might suit a problem better than another, thereby what usually happens in a real-life material selection, is a mix of them. Furthermore, all these methods might include different considerations according to the field of application. In interior design, the range of aspects to take into account when choosing materials are several. Those range from strictly technical, such as materials properties and building codes and regulations, to more sensorial, psychological or health-related ones. Another factor to take into account during the material selection is indeed the toxicity of materials. Interior designers share the responsibility to create spaces that support safety and human health thus, another aspect to reckon are the effects on humans wellness (Binggeli, 2014). One of the main concerns regarding human health in enclosed spaces is related to indoor air quality (IAQ) because it can impact people's health, comfort, wellbeing and productivity. IAQ can be compromised by noxious or toxic vapours off-gassed by occupants or provoked by building-related matters (Jones, 2008). Building related pollution may originate from exterior sources, ventilation systems and construction methods but also by materials and finishes. In fact, almost any man-made or natural material in confined spaces is associated with invisible and sometimes odourless fumes or vapours called volatile organic compounds (VOC). Many VOCs are toxic and can affect the central nervous system, provoking physical symptoms (typically eye and respiratory system related) or psychological irritation. Consequently, it is critical to be aware of VOCs and avoid materials and finishes that might off-gas them (Pliatowicz, 1995).

Furthermore, material selection can and should be aimed at causing the lowest environmental impact. To achieve so it needs to be seen with a systemic approach and therefore take into account the whole life cycle of the space. The main strategies to carry out a more environmentally sustainable material selection can be summarized in the three Rs rule: reduce, reuse, recycle, to which it would be right to add using renewables when it comes to specifying building materials. Reduce the need for materials, reuse the ones already in use, recycle the ones that cannot be reused and ensure that any new material used is renewable (Moxon, 2012).

REDUCE

Reducing material consumption is a practice that denotes a design aimed at minimizing the usage of materials. Reducing the materials used in a project means not only diminishing the amount of raw material, but also packaging and waste, and consequently reducing the associated consumption of energy and water, transportation, and air pollution (Moxon, 2012). By doing this designer can diminish the environmental impact, not just because fewer materials are pre-produced, but also because of their transformation, transport, and disposal are avoided (Vezzoli, 2014).

Reducing material use can be achieved by:

- Avoiding raw materials and questioning whether certain materials or products are needed at all.
- When specifying new materials is unavoidable these should preferably be rapidly renewable, salvaged, reused or even untreated or self-finished.
- Using materials efficiently, for example by using a wide metal mesh rather than a solid sheet.
- Ensuring that materials are hard-wearing and seldom require maintenance. Indeed, durable materials are less likely to need to be restoration or fast replacement. (Moxon, 2012).

REUSE

Reusing prevents existing materials from going to waste in landfill and saves on the embodied energy and water that would have been necessary to produce replacement materials. In practice, reusing is often inextricably linked to reducing, as using existing materials can reduce the need for new ones. Reusing avoids the need for many virgin raw materials and all the environmental problems they cause throughout their life cycle.

Reusing practices materials includes:

- Salvaging demolition waste or selective demolition, that consists of the dismantling of reusable building parts for reuse and provide low-cost construction materials
- Using reclaimed materials
- Ensuring that specified materials can be reused at the end of the project. This practice is related to design for disassembly, that consist of designing products to be taken apart at the end of their useful lives in order to facilitate reuse and recycling. Indeed, considerations on the sustainable characteristics of the materials themselves are important but it is the assembly of the materials into buildings components, which work together to create sustainable options, that is crucial (Godsey, 2017).
- Repurposing materials for other uses or applications

- All those practices improve the life span of materials, meaning that they valorize them and that allows them to be reused, repurposed or reprocessed to obtain new secondary raw materials. This approach implies to choose not only materials with efficient recycling technologies but also designing in a way that facilitates maintenance and disassembly (Vezzoli, 2014).

RECYCLE

Recycling diverts waste materials from landfill and reduces the extent of virgin resources needed to make new products. To promote recycling, interior designers can choose recycled-content products and ensure that the materials they specify can be recycled at the end of the project's life. Moreover, designers should also check that local recycling systems can recycle the materials they specify. Indeed, although many materials are theoretically recyclable, not every facticity is able to recycle them. The best scenario would be to choose a product covered by a manufacturer recycling system such as Interface floor that, with the programme ReEntry, collects carpet tiles at the end of their life and recycles them (Interface,2018). Moreover, designers should be aware that products made of single materials are easier to isolate for recycling than composites made of several materials fused together, and that also finishings may affect recyclability. Overall, recycling is a fundamental practice but it still consumes energy, water, and needs transportation thus reusing is more effective (Moxon, 2012).

RENEWABLES

A resource is renewable when the acquisition rate is smaller than the natural re-growing rate (Vezzoli, 2014). When selecting new materials those should be rapidly renewable, meaning that they replenish themselves faster than traditional extractions without biodiversity loss, increase erosion or air quality changes. Specifying these or materials with recycled content divert materials from the solid waste stream and reduce the environmental impacts of producing new construction and product materials. Moreover, when choosing raw materials is inevitable, designers should make sure that those come from sustainably managed ores or harvests, and that the materials are extracted and manufacture close to the project site (Binggeli, 2014) in order to avoid further GHG emission during transportation. By keeping these expedients in mind, interior designers can broadly evaluate material's sustainability and make environmentally conscious choices during the selection process, without needing expensive and time-consuming LCAs, when their accuracy is not required. Nonetheless, it is fundamental to mention that there is no such thing as "sustainable material". One building material can only be considered sustainable (or not) when understood in the context of the design, climate, and culture it is used within over time (Petrovic, 2017). The most environmentally sustainable materials are renewable or regenerative ones, which are materials that can be acquired without ecological damage and are used at a rate that does not exceed the natural rate of replenishment (Binggeli, 2014) Hence, they should be drawn from a resource so vast that its use by man has no effect on supply (like seawater), be recreated in perfect form after use (like ice in the artic) or regrow as fast as it is used (the biosphere, if properly managed). Examples of the first two are rare and it is, therefore, the third, the management of the biosphere, on which we must depend for truly renewable materials (Ashby, 2012). The materials that fit this definition are derived from vegetal, animal and mineral resources and includes materials such as wood, grasses, stones, clay, cellulose and protein-based fibres.

The subsequent pages present case studies of bio based materials and products for interior applications.

Biobased materilas

SCALITE

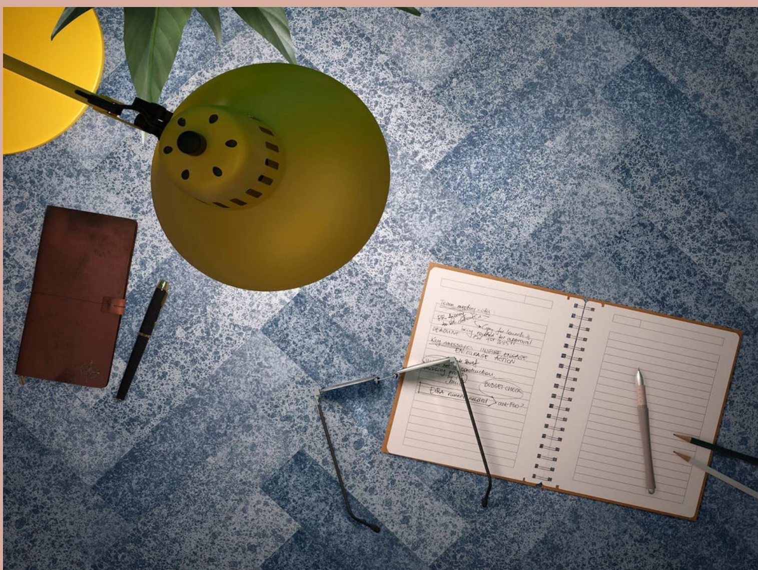
SCALE
FRANCE
2016

SCALITE (SCALE, 2020) is a bio-sourced material entirely made from fish scales, a by-product of the fishing industry. Being 100% natural and containing no chemical additives, SCALITE degrades rapidly in the environment. SCALE aims indeed at creating only non-deleterious and non-poisonous materials, which are made from marine raw material and will dissolve swiftly in a marine environment. Moreover, being VOC and formaldehyde-free and having similar mechanical properties to those of MDF, it has the potential to become a substitute to it in interior environments. The material is thus produced in rigid sheets of various sizes, shapes and colours (SCALE, 2020).

Figure 3.3
SCALITE sample

- Recyclable: the production waste can feed into new material production (can be done only by SCALE)
- Seamless joints: SCALITE can be joined seamlessly to provide architects and designers with uniform appearance.
- Glueless bonding: SCALITE can be bonded without conventional glue, using its own resin.
- Conventional timber tooling: SCALITE can be transformed using conventional tooling such as saws, spindles, CNC, sanding equipment.
- Low energy production methods: the manufacturing process has low energy and water consumption and use no harmful chemicals.

Figure 3.4
SCALITE example of use

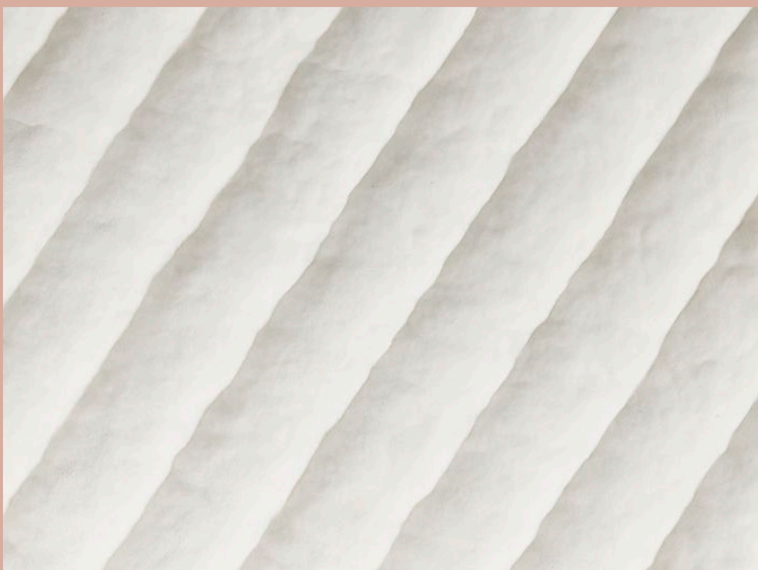


MOGU

MOGU
ITALY
2015

Mogu (Mogu.bio, 2020) is an Italian company that produces commercial mycelium-based products suitable for interior design applications.
Strains of mycelium, the vegetative stage of mushrooms, are grown on pre-engineered substrates made of agro-industrial residues (matrix). By tuning the matrix configuration, different materials are harvested within short timeframes and with limited use of resources. Fungal mycelium acts as a reinforcement to the matrix structure, creating a 100% plastic-free and coherent material composite. At the end of the production process, mycelium materials are inertized by slow drying, for reduced energy consumption. The resulting products are stable, safe and durable and biodegradable (Mogu.bio, 2020).

Figure 3.5
Texture of Fields acoustic panels by Mogu



- Mogu produces acoustic tiles and flooring materials.
- The products are VOC free, moisture-proof, easy to fix and fire-resistant.
- Mogu claims to produce products which are designed and crafted with the lowest environmental impact possible, to offer radically innovative experience.
- Mogu is committed to run its production processes starting from low-value materials, which cannot find any other valuable application in the industry. By feeding on the organic matter, and thanks to Mogu's design and engineering skills, the mycelium converts the low-value input matter into a product with high added value, characterised by unique aesthetics (Mogu.bio, 2020).

Figure 3.6

Fields acoustic panels by Mogu

FOAMED PULP

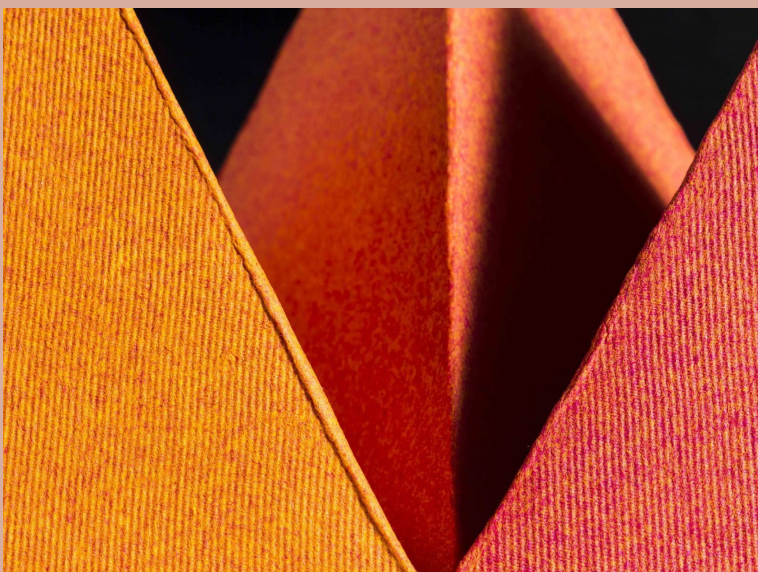
AALTO UNIVERSITY & VTT
FINLAND
2018

Tiina Härkäsalmi, Jukka Itälä (Aalto University) & Jani Lehmonen, Jukka Ketoja (VTT) developed a foamed pulp that could be used in the production of sound-absorbing and insulating panels. The material is the result of a five-year-long experimental journey in cellulose possible uses in the future (Kataja, 2018). It is semi-rigid, has a surface hardness that goes from semi-hard to soft, has good acoustic properties and the material's density, stiffness, permeability, heat insulation or sound absorption can be tailored.

The panels, being entirely made of cellulose and little foaming agents, are biodegradable, recyclable, and with a low Carbon Footprint. Indeed, the foam-forming process is simple and requires a relatively light infrastructure. Moreover, the form of the panels can be

Figure 3.7

Foamed pulp, detail



customized on multiple scales by moulding with e.g. laser cut and vacuum-formed plastic mould, or 3D printed mould (Kataja, 2018).

The material, as many other cellulosic materials, does not yet fulfil all the general technical demands of construction materials but it is still a good experimental result and hope for the future.

Figure 3.8

Foamed pulp

CELLULOSE ACETATE vs POLYCARBONATE

RESEARCH

During the course “Design Meets Biomaterials”, an interdisciplinary course held by Aalto University, the author of this work in collaboration with Kitty Zheng (B.A. Architecture) and Tim Moesgen (M.A. Collaborative and Industrial Design), researched the possibility of substituting oil based plastics used in buildings and interiors with cellulose based alternatives.

In Europe the construction sector accounts for approximately a 20 % of the total consumption of plastic materials (AMIPLAS,2016). Plastics in buildings have many applications because of their durability, good insulation properties, ease of maintenance and low costs. However, oil based plastics also have many drawbacks: they emit greenhouse gases, are not renewable and have low recycling rates.
Therefore, the group decided to research bio based alternative to oil based plastics used in construction. The team interest was caught by the possibility of obtaining transparent plastic from wood, and in detail by a cellulose based compound discovered in 1865, cellulose acetate (CA).
Cellulose acetate is a synthetic compound derived from the acetylation of the plant substance cellulose that, until the 1940’s, when petroleum-based polymers got popular, was widely used in photography films, aircraft dope and automotive industry equipment (Encyclopaedia Britannica, 2009). It’s general properties and manufacturing methods are similar to those of Polycarbonate (PC) so the team decided investigate whether it was a viable alternative to this oil based plastic.

However, there are different types of CA. The team decided to explore three of them:

- Cellulose Diacetate (CDA)
- Cellulose Triacetate (CTA)
- Cellulose Acetate Butyrate (CAB

Figure 3.9

Polycarbonate VS Cellulose Acetate adapted from Material Properties Database

	main properties	traditional manufacturing methods	environmental impacts
CELLULOSE ACETATE	Elongation at break (%) Flexural modulus (GPa) Flexural strength (MPa) Ultimate tensile strength (MPa)	Extrusion Dyeing Injection molding Milling	Obtained from renewable resources Biodegradable (can be improved with some plasticizers)
POLYCARBONATE	Glass transition temp. (°C) Specific heat capacity (J/kg-K) Thermal expansion (µm/m-K) Density (g/cm3)	Extrusion Dyeing Injection molding Blow molding Thermoforming 3D printing	Potential human exposure to harmful BPA in food contact 100% recyclable Bio based polycarbonate is expensive

When comparing these 3 materials CAB showed overall better characteristics. It has a lower melting range, water and moisture absorption and higher flexural strength. It is tougher, more durable, and has better dimensional stability, better weathering resistance as well as good ultra-violet resistance.

Given the noteworthy properties of the material, the group developed a concept for a honeycomb cellulose acetate panel that could substitute cellular polycarbonate sheets.
Honeycomb structures made of polycarbonate are already used in construction because they're light, strong, hard and stiff and, in the case of polycarbonate, semi-transparent. The idea would be to produce a translucent or transparent cellulose acetate honeycomb panel that can be used as partition walls and would consist of a CAB core sandwiched between CDA facing sheets.
The panels could be produced by moulding, with slits and fold lines and dried into honeycomb shapes or could be made by inflating, like the MIT self-folding inflatable origami.

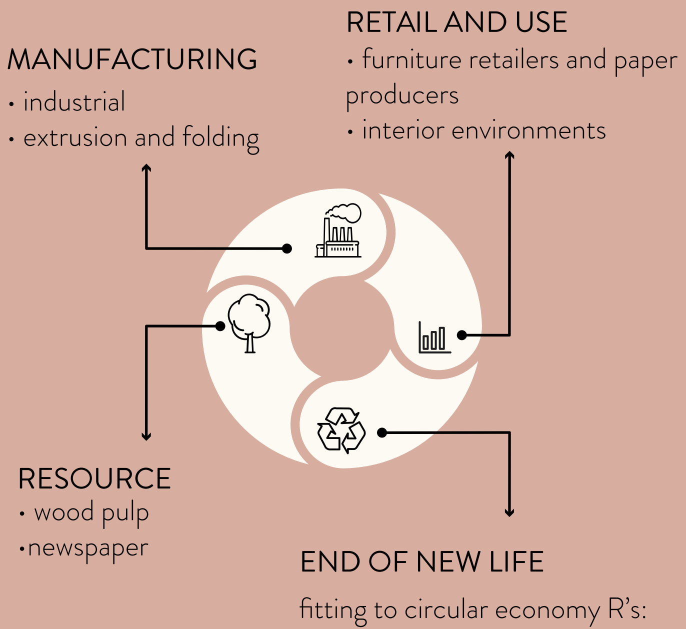
The life cycle of the product has been imagined to have a broader view of its sustainability.
The material could be made from wood pulp or cotton but, according to some researchers, also sugarcane bagasse (Candido, 2017) and newspaper (Rodrigues, 2008) could be viable resources. The panels could be then manufactured in industrial facilities through a combination of extrusion and folding. Furniture retailers or even paper producers could sell them as a partition in interior spaces such as offices, shops and schools. When then thinking about its end of life the product could have a new life and fit into some of the circular economy's Rs. The panels, if made with CDA, could potentially have better resistance to UV light than PC and thus have a longer lifetime and being REUSED in different applications. Moreover, being made of a thermoplastic, those panels could be

REMANUFACTURED. The product could be then also RECYCLED. Information regarding the recyclability of CDA plastics haven't been found but, being a thermoplastics, it can be assumed that recycling is viable. However, their recycling couldn't take place within the paper products but it should have its own recycling chain. This may seem a disadvantage but it could actually help in achieving higher recycling rates.

If not recycled the panels could be RECOVERED (industrial biodegradation) thanks to the presence of environmentally sustainable plasticizers triacetin (TA) and diacetin (DA), which have low toxicity and can improve the material' biodegradability (Phuong,2014).

Figure 3.10

Life cycle



As mentioned in the previous Chapter, materials not only have impacts on psychology and physiology of human beings but also affect their perception of a space. Thus, could they foster more sustainable behaviours?

A study carried out by Katholieke Universiteit Leuven, Vrije Universiteit Brussel and Delft University of Technology investigated the possibilities of relating material experience in architecture to technical material parameters and offered insight on how to change the experience of warmth through colours, finishes and materials. The perception of warmth of interior building materials is the result of the composite percept of the visual, tactile, and possibly other sensory characteristics. According to the research, the vision has a very large impact on the general assessment of material warmth within an architectural context. This is due to colours but also due to the visual glossiness or roughness of surfaces. As the former is quite well know, colours ranging between yellow and red-violet on the colour circle (i.e. yellow, orange-yellow, red, and red-violet) are described as warm, while those that range between blue-violet and yellow-green on the chromatic circle (i.e. blue-violet, blue, blue-green, yellow-green) are perceived as cold, the latter is relatively new (Wastiels et al., 2012). Space with smooth walls seems colder than a comparable space with finely textured walls and this is because a fine texture is associated with porosity and, thereby, with a warm and protected space.
A similar research on the perception of warmth has been conducted by Aalto University and the University of Helsinki. The research showed how two materials commonly used in floors wood (pine and oak) and ceramic tiles, can be perceived as being thermally different despite having the same surface temperature (Bhatta et al., 2019). According to these findings, a space with wooden floors and orange textured walls could be perceived ad warmer than one with ceramic tile flooring and light blue walls despite having the same physical temperature.

This means that a careful selection of materials and finishes, and knowledge of human perception could reduce the energy required in buildings for heating and cooling.

3.1.3 Understanding assemblies

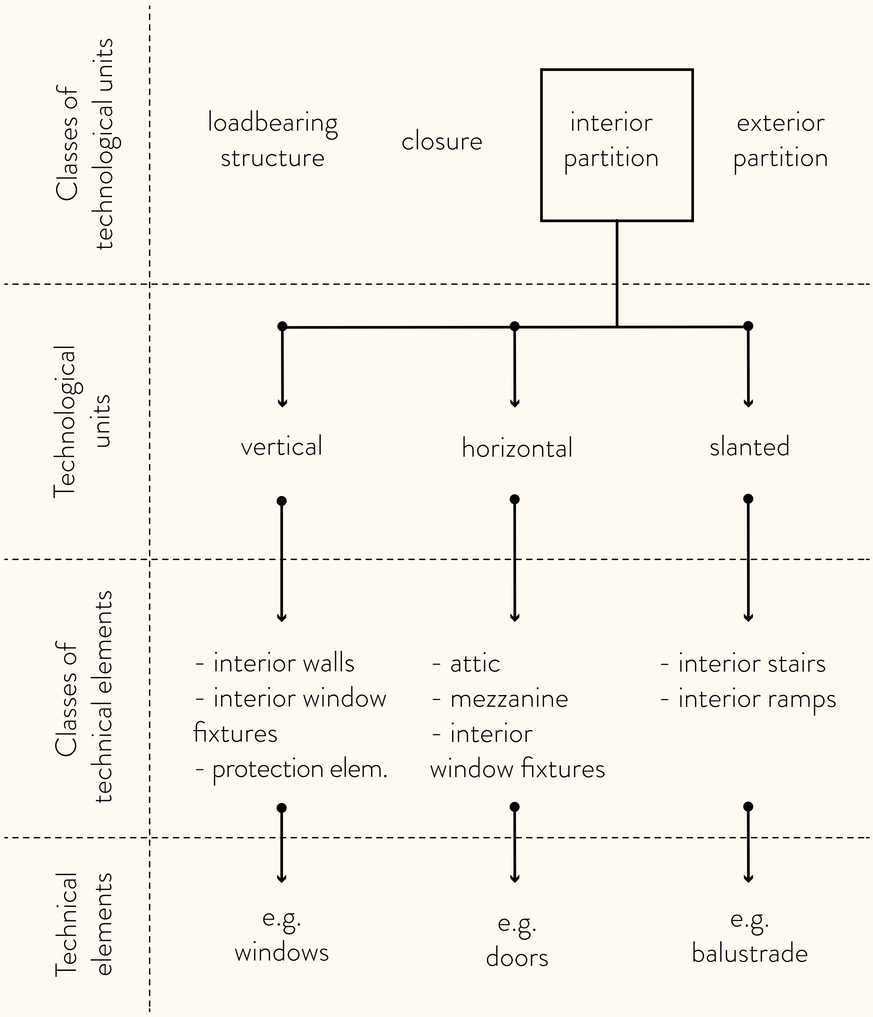
The choice of materials is essential but how the materials are combined is just as relevant. Spaces are indeed defined by enclosing elements such as walls, floors and ceilings, that are made of more than one material. Understating what those elements are, how they are formed and how they function is crucial to comprehend how to improve the sustainability of an interior.

Floors, ceilings and walls not only define interior spaces but foremost they have structural functions and can be considered subsystems of a bigger system, the building. Buildings can be looked at as systems made of more or less complex components, that can be farther divided into smaller systems according to their specific functions. The Italian building system is defined by

UNI 8290, that divides it into two subsystems: environmental and technological. The latter is then divided into further levels, each with different degrees of complexity (figure 3.11)

Figure 3.11

Classification and breakdown of the building system - UNI 8290

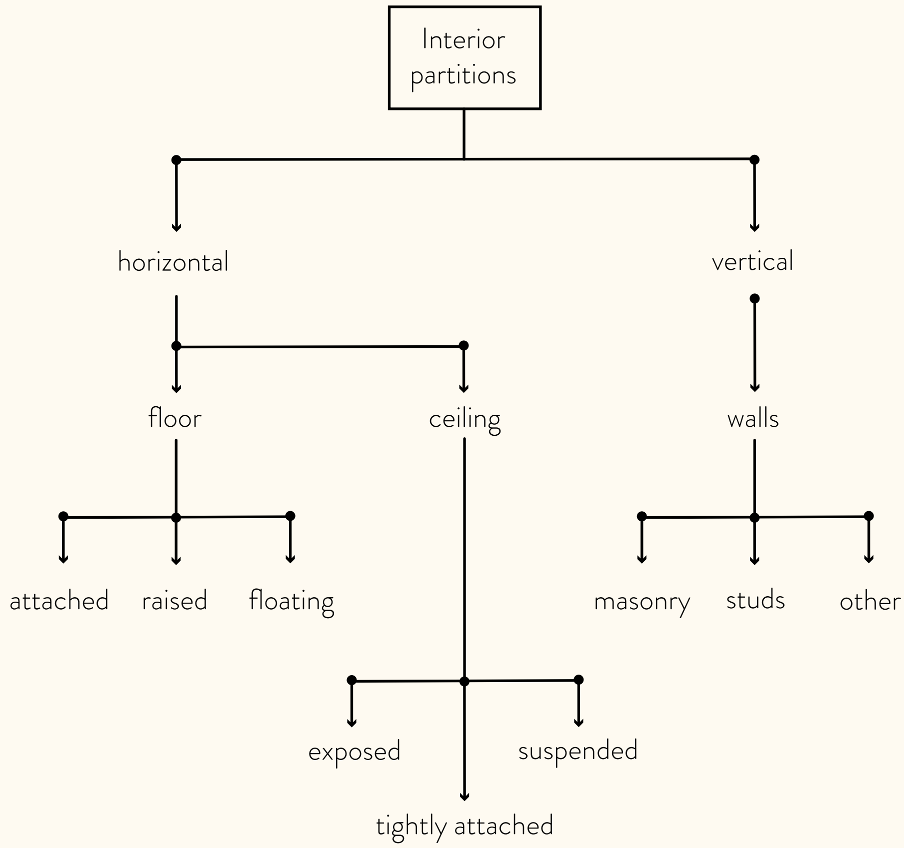


Taking into account this classification can be relevant but not very useful to understand where and how the interior designer can intervene. Therefore, by following UNI 8290 and other sources, a diverse division of the system characterising interior has been developed, in order to have a more clear view on interior designers possibilities of intervention.

In this classification walls, ceilings and floors, have been further divided into categories that distinguish when the interior designer intervene only with finishing materials (exposed and tightly attached ceilings, attached and floating floors, masonry walls) and when he/she introduce extra structure (suspended ceilings, raised floors, framed, and other walls,) and therefore uses what can be called building materials.

Figure 3.12

Classification of interior partitions



Interior partition

In this work, the term interior partition refers to all the systems and surfaces that describe the interior space, without distinguishing between those that separate outdoor and indoors and those that divide and shape indoor spaces.

- Horizontal interior partitions
  Horizontal interior partitions will refer to floors and ceilings, those technological unites that in UNI 8290 are referred to as "intermediate horizontal closures".
  Horizontal interior partitions take into account floors and ceilings. These, being two faces of the same structural system, can be considered as an assemble. A floor/ceiling assembly is generally constructed from concrete slabs, wood or steel and its depth is related to the size of the structural bays that it spans and the strength of the materials used. This affects the interior height from ceiling to floor as well as total building height. Moreover, each assembly differs from others in fire and acoustic ratings, components and thickness, because it might accommodate mechanical, plumbing, and electrical equipment (Binggeli, 2016).

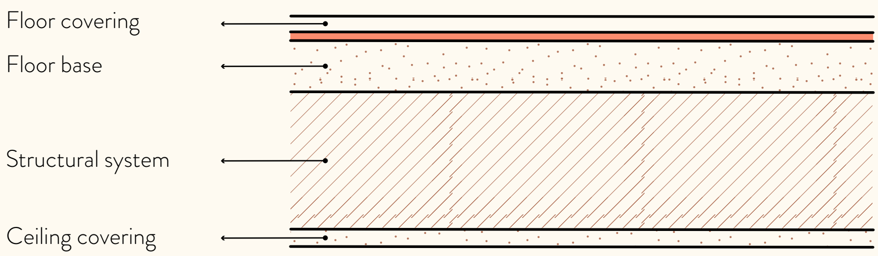
  Floor /ceiling assemblies can be analysed considering 4 layers: floor coating, base, structural system and ceiling coating (Figure 3.13).

  However, a void or plenum is sometimes added between the structural system and the coverings. This is the case of suspended ceiling and access floors.

- Vertical interior partitions
  Vertical interior partitions will refer to walls, and in detail to those technological unites that in UNI 8290 are referred to as "interior vertical partitions" and "exterior vertical partitions". For the latest, only the side facing the indoor space will be taken into account.

Figure 3.13

Floor/ceiling assembly



FLOORS

Floors are the flat, level base planes of interior spaces. Their prior function is to provide structural support, but they do much more than just that. Indeed, floors interact with numerous other building systems such as lighting, ventilation, heating, and depending on the materials used, also affect the acoustics, humidity and thermal qualities of a room. Furthermore, floors are the primary wearing surfaces of a building. They are subject to water, grit, dust, and the abrasive and penetrating actions of feet and furniture. They require more cleaning and maintenance effort than any other component of a building (Allen, 2014). Therefore they must be designed to withstand the use intended for that specific space (Binggeli, 2016).
However, floors have also a lot to do with our visual and tactile appreciation of a space. We sense their colours, patterns, and textures, their "feel" underfoot, and the noises they make in response to footsteps. They interact in various with light affecting the brightness of the space (Allen, 2014).
Floors can be:

- Attached
  A floor can be considered attached when the floor bases and coverings are directly attached to the structural systems. However, the essential structural components of floor construction, with the exception of good-quality tongue-and-groove boarding or sheeting, do not offer an acceptable finish or base for finishes for any but the most utilitarian contexts. It is, therefore, necessary to introduce other layers (Figure 3.13) between the structural floor and the finishing materials.

- Raised /Access
  Access flooring systems are typically used in office and institutional spaces to provide flexible placement of furnishings and equipment as well as access to mechanical and electrical equipment below the floor. The system consists of removable floor panels supported on adjustable pedestals. The pedestals can raise the finished floor height up to 455 mm; minimum heights vary. The steel, aluminium, or lightweight reinforced concrete floor panels are 610 mm square. They may be finished with carpet tile, resilient tile, hardwood, terrazzo, or porcelain tile, or other finishes. Finishes with fire ratings and designed with electrostatic discharge control are also available (Binggeli, 2016).

- Floating
  Floating floors are flooring systems that are not nailed or glued to the subfloor, but instead "float" above it on a thin pad of resilient foam. These floors are made by connecting the individual pieces of flooring together at the edges to make one continuous piece as large as the room in which the flooring is laid. Edge glueing is the most common way of making this connection, but systems are available that use metal clips or interlocking edge details. A gap, that is later covered with baseboard trim, is left at the edges to permit expansion and contraction of the floor (Allen, 2014).

Figure 3.14

3-8, by Leopold Banchini

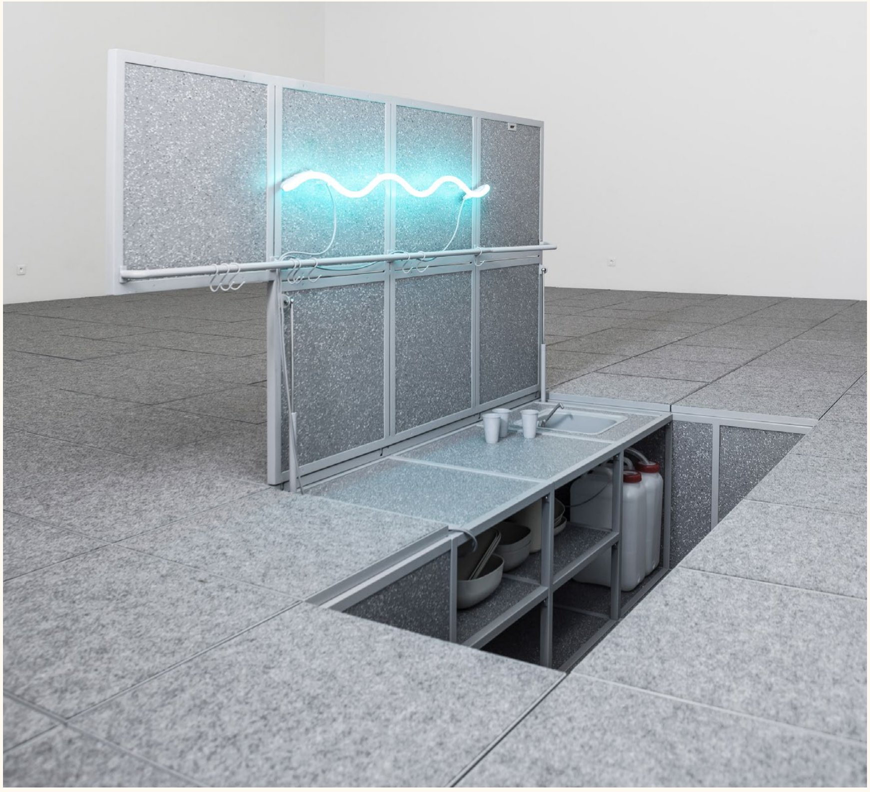


Figure 3.14 features an installation by Swiss architect Leopold Banchini at the Centre Pompidou in Paris. Named 3-8, Banchini's permanent installation consists of a space constructed to appear like technical raised floors, which in this case, instead of hiding services, hides usable facilities. Sections of the floor are indeed hinged and can be lifted up to reveal a variety of hidden spaces beneath, allowing the users to alter the space for different needs (Ravenscroft, 2018).

CEILINGS

Ceilings are the underside of floors and although their importance is often underestimated they play a major role in interiors both functionally and aesthetically. Indeed, they affect the diffusion of light and sound about the room. They help control thermal radiation, air temperature, humidity and they are often designed to resist the passage of fire. Frequently, ceilings are called upon to assist in the distribution of conditioned air, artificial light, and electrical energy. Moreover, ceilings colour, texture, pattern, and shape are prominent in the overall visual impression of the room (Binggeli, 2016; Allen, 2014).

Ceilings could be divided into three main categories:

- Tightly attached
  Almost any material can be attached directly to the underside of the structure above. Commonplace examples include gypsum board or plaster mounted directly to the underside of wood or steel joists and rafters, acoustical tile adhered to the underside of a concrete deck, textured acoustic materials spray applied to the underside of concrete slabs or corrugated metal decking (Allen, 2014).

- Exposed
  In exposed ceilings, the structural grid and the systems are shown (figure 3.15). This allows to achieve the maximum possible floor to ceiling height and eliminate the cost of installing a ceiling. However, the cost of designing code compliant and visually pleasant systems arrangements may exceed the one of a ceiling.
  In this case, the interior designer possibilities of interventions aren't many and consist mainly in finishes such as paints.

- Suspended
  Suspended ceilings are composed by a hanging system and a finishing material. The hanging system, through wires or frames, suspends the finishing materials below the structure of the floor, providing space for electrical and mechanical lines, recessed lighting fixtures, and insulating materials (Binggeli, 2014). This type of ceiling requires not only finishing materials but also building materials to realize the supporting structures.
  The supporting suspended structure is usually made with wooden or metal studs, or wires, according to the finishing material that will be applied, while almost any material can be used as finishing material. The ones most widely used are gypsum board, plaster, and various proprietary panels and tiles composed of incombustible fibres or other material (Allen, 2014). The tiles or panels are usually removable for access to the plenum.

WALLS

Walls are vertical building elements that enclose, separate, and protect interior spaces. Walls are often designed to support loads transferred from floors and roofs but are sometimes a framework of columns and beams with non-structural panels attached to or filling in between them. Walls, like floors, serve many building functions. They house different systems and control thermal radiation, air temperature, humidity, airflow, acoustic and visual privacy (Binggeli, 2016).

When a wall provides structural support it's called loadbearing. Loadbearing walls are often constructed of concrete and masonry, but can also be built with metal or wood studs, and are classified by building codes as non-combustible construction. If stud frames are used, those can be assembled on-site or panelised off-site. The relatively small, lightweight components are easily worked into a variety of forms.

Figure 3.15

Exposed ceiling in Storey office by Waugh Thistleton Architects

The cavities between the studs are used for thermal insulation, vapour retarders, mechanical distribution, and mechanical and electrical service outlets (Binggeli, 2016). Interior designers do not intervene on the structure of load bearings walls but only on the finishing surfaces.

A wall that doesn't carry loads is called non-loadbearing, and in case it subdivides the space within a building it can be also called "partition". Its construction should be able to support finish materials, provide acoustical separation, and accommodate connections to mechanical and electrical distribution services. Interior walls are commonly made with wood or metal studs frames and plaster or gypsum boards. Concrete masonry partitions are also used and may be plastered or faced with gypsum board but are more often left exposed, either painted or unpainted.

Almost all the finishing materials that can be applied to loadbearing masonry walls can also be applied to non-loadbearing studs and panels walls but different installation methods might be used.

Other than loadbearing or non-loadbearing, walls can be categorized according to their construction method or main materials used. This type of classification allows to better understand the interior designer possibilities of intervention.

Three possible categories are:

- Masonry
  Masonry walls are usually loadbearing walls made with bricks masonry plastered on both sides or concrete blocks plastered or faced with gypsum board or left exposed. Masonry walls have excellent acoustic and fire resistance ratings but are labour intensive and heavy.
  If plaster or gypsum board surfaces are to be applied over a masonry wall, they may be spaced away from the wall with either wood or metal furring strips.

- Studs
  Studs partitions are made with metal (aluminium) or wood (softwoods) studs that create a skeleton structure on which plasterboard claddings are fixed. Plasterboard sheets consist of a core of gypsum plaster between two skins of paper. One side, the lighter coloured, can be painted directly for a finished surface or used as a base for a plaster "skim[9]" coat. Studs and panels partitions have much quicker construction method than brickwork, blockwork, concrete or the traditional lath and plaster and have no lessening in quality of finish but have reduced acoustic performance (Plunkett, 2015). Moreover, due to their relatively small pieces and the variety of fastening techniques available, they are quite flexible in form. Cavities in the wall frame accommodate insulation and mechanical and electrical distribution. The finish materials determine the fire-resistance rating of the wall assembly (Binggeli, 2016).

- Others
  Separating interior spaces can be also done in other ways. The possibilities are endless, from simply bookshelves, wardrobes or other furniture, to free-standing panels, blocks, curtains and even plants. Inspirations can be found in offices, that have always faced the issue of separating spaces with temporary solutions, but also in stores, houses and exhibitions. Figure 3.16 shows a free-standing expandable paper partition designed by Molo. The product can be made of paper but also textile and has the peculiarity to be thick as a book when compressed but even 4,5 meters long when totally expanded. Moreover, Molo's partitions are movable, can be shaped in any curved or linear formation and therefore allows for space flexibility (Molo, 2020).

All these systems result from the combination of numerous materials, fixed together through different means and build with various methods. These can determine an interior's thermal performance and maintenance requirements, not only affecting energy use but also and foremost waste production. Waste is mainly produced during construction and refurbishment or demolition of an interior. Interior designers can favour the construction of environmentally sustainable interiors by designing for disassembly and preferring modular and standard solutions.

Note

[9] Skimming is the name provided to a plastering method where a wall is plastered with a layer of thin coat. It is usually applied to an existing plaster to smooth the surface area. From: https://plastering.quotatis.co.uk/whats-difference-plastering-skimming/

Figure 3.16

Molo paper softwall / folding partition

3.2 Strategies

The previously made considerations unveiled the complexity of designing environmentally sustainable interiors and suggested some indications but didn't provide design strategies. Starting from the reflections made in sections 3.1.1, 3.1.2, 3.1.3, through literature researches and investigation of case studies, some common approaches that can lead to environmentally sustainable interior design have been identified and will be described in the next pages. The possible strategies are many and vary across the type of projects and contexts. Spaces with different lifetime, purposes, functions, users, and locations have diverse design requirements and, therefore, will require diverse sustainable measures (Moxon, 2012).
In this work have been pinpointed six strategies. They vary for their focus on the project but are all related to the R's "mantra" and pay attention to the lifetime and the life cycle of a project. Some approaches might seem not intrinsic sustainable but can still lead to increased sustainability.

SIMPLICITY

Simplicity is a concept with various meanings that, when dealing with interiors, can be related to shapes, materials, layout, uses, etcetera. Simple, and for some aspects minimal, interiors are characterised by elementary forms and details, a reduced spectrum of materials, and decreased usage of decor. As a result, spaces are maximally relaxed, functional and elegant. A space with these features is less likely to be affected by fashion and trends and therefore can be considered timeless. This means that it could have a longer lifetime and thus consume fewer resources. Moreover, the minimalistic approach is also considered a good practice when it comes to sustainable design because, due to the proper choice of materials applied, simple forms and the reduced quantity of used furniture, it implies a responsible use of resources (Petričević, 2007).

Planning simple interiors can be particularly relevant when working within an existing building. This is rather a common situation for interior designers and, despite being often considered a constrain, it is important to recognize that the very nature of inheriting an existing building or space means reusing something old or obsolete, rather than throwing it away and starting anew. "Many interior design projects are therefore already taking a basic sustainable approach at their outset, preventing buildings going to waste and saving on the need for new materials. Interior designers have a great opportunity, and indeed the duty, to upgrade and breathe new life into these spaces. There may be elements that are restrictive and others that are beneficial, but the best approach is to look at what exists, make good use of it, and improve it" (Moxon,2012).

The application of this strategy is clearly visible in Studio Nordest Arquitectura office (Figure 3.2). The Studio used simple pale timber partitions to transform a 180-year-old barn into an office space. The same material has been used for all the built-in furniture and the entrance door, giving the office a humble but elegant appearance (Block, 2020). The project tries to respect all the original building elements, showing them the maximum possible and accepting the modified parts during the life of the building, keeping the once that are useful, and deleting the ones that can't be useful for the new use of the building (Nordest Arquitectura,2020).

Figure 3.17
Nordest Arquitectura office

FLEXIBILITY

Another sustainable practice is that of designing flexible spaces, or rather spaces that can evolve and adapt to new and different functions. These spaces have the ability to be variable and adaptable to changes in the lives of users or in relation to the use which these will make over time. This allows to maximise the use of available space and alter rather than replace or demolish interiors when its occupants' needs change (Canepa, 2017). Overall, space flexibility is not only sustainable, because it helps saving materials and resources, but it also foster innovation, creativity and calls for interior designers to forward-thinking to create adaptable and practical spaces (Moxon, 2012).

An example of flexibility is MJE House, by PKMN Architectures. The studio renovated the apartment by inserting mobile partitions and furniture systems that changes the traditional concept of a room. Indeed, the added modular storage walls, made of a light steel skeleton and panels of white-coated wood, can be moved through simple gestures. This allows the space to be easily transformed from a quiet loft into a party venue in a few seconds and host a different number of people without permanently dividing the space into a lot of small rooms (Morby, 2016).

Figure 3.18
MJE House

MULTIFUNCTIONALITY

A somehow similar approach is that of multifunctionality, that allows to save both resources and space by having one room or piece of furniture that serves multiple functions. Differently from a flexible space, a multifunctional one doesn't change much. It is instead able to serve different function at the same time, in the same space, without many changes. Thus, a multifunctional space can be described as the integration of different functions in time and space. Moreover, designing with multifunctionality in mind enables to obtain more from small spaces and consequently be satisfied of smaller homes or offices.

A project that embraced this strategies is "A Room for Two", by Studio Ben Allen. In 2017 the studio has built a plywood structure to create a bedroom for two children. The pale birch plywood insertion creates a pair of bedrooms and studies, with all the necessary functions, including storage units and desks, built-in. Each space is provided by its own arched entrance, creating two "miniature houses", each conceived differently to adhere to the ages of the children. This solution allowed the architects to minimize the use of extra materials and furniture (Gibson, 2016)

Figure 3.19

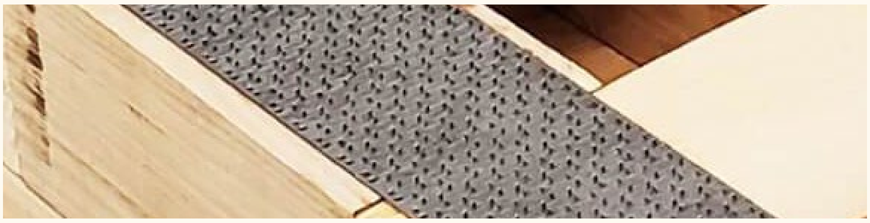
Room for two

DISASSEMBLY

The conventional material end-of-life processes such as demolition, transportation, and disposal to landfill have environmental implications (Ezema, 2019). Design for disassembly and recovery is a practice by which buildings and interiors are designed and assembled to facilitate future changes and the eventual dismantlement (in part or whole) for recovery of systems, components and materials. This practice not only creates enduring projects but also transform buildings and interiors in materials banks by ensuring that everything used in the interior can be reused or repurposed. Furthermore, spaces designed with possible future disassembly are more flexible, easier to repair, refurbish, or reconfigure (C2C Certified, 2017).

Consequently, interiors should always be constructed with a view to deconstruction. Designers should prefer construction methods that ensure materials and components to be differentiated and easily detached from the whole at the end of the project life. This can be achieved by avoiding bonding mixed materials and selecting mechanical fixing methods that allows future separation such as hooks, clamps, screws, and bolts. Adhesives should be avoided because not only they make assemblies more difficult to dismantle, but also because they can offset VOC and thus cause health problems to both installers and final users. Wet construction methods, such as bricklaying, plastering, and cement mixing, not only use a lot of water, therefore it would better to avoid them, but also prevent deconstruction.

Figure 3.20
Grip Metal



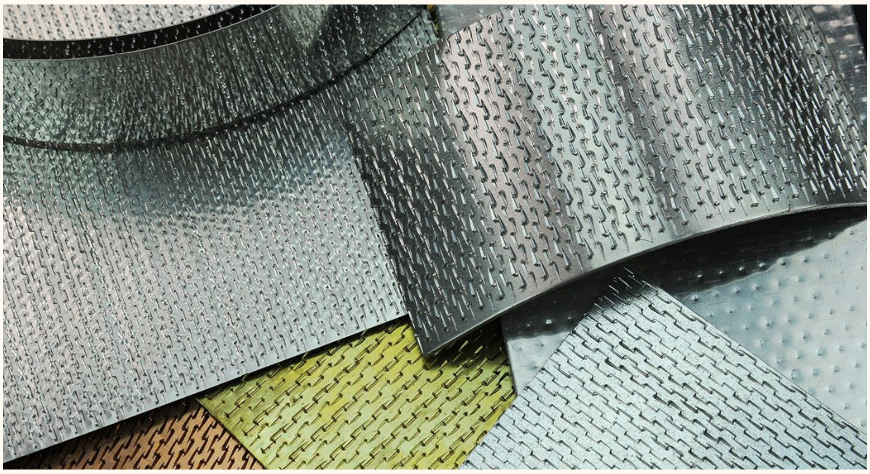


Figure 3.17 shows GRIP Metal™, a technology for a mechanical bonding between material layers. GRIP Metal™ consists of a thin gauge sheet metal with thousands of mechanically extruded hooks which allow mechanical bonding between different materials. GRIP metal can be made with nearly any coiled metal, is available in a wide range of materials and sizes, and has hooks that vary in height according to the materials that need to be bonded and the force that they need to resist. The product allows connecting materials without the use of adhesives by acting a Velcro and thus distributing the attachment load over a wide area and many contact points. This system of mechanical bonding has a higher quality of bond than that achievable with adhesives, does not offset VOCs, is suitable for both indoor and outdoor applications and is less expensive in terms of energy and materials compared to the conventional way.

Figure 3.18 gives another example of good design for deconstruction. Note Design Studio designed a re-usable stand for Vestre, a Norwegian urban furniture brand, at Stockholm Furniture & Light Fair. The installation features walls clad in uncut sheets of plywood, stands built up of uncemented bricks and a floor of stone chips. No adhesives or screws have been used making the whole stand fully reusable or recyclable.

Figure 3.21

Vestre's stand at Stockholm Furniture & Light Fair

MODULARITY

Designing with modular blocks or prefabricated construction modules allows saving time and resources. Indeed, prefabricated solutions are assembled under controlled factory conditions and delivered to site just in time for installation avoiding waste from cutting to size, over-ordering, or damage during storage. This hastens the construction process and, if transportation is not a major concern, decreases emissions resulting from construction activity. Prefabricated solutions not only scale back effects to the environment and the site during construction but also in operation due to the higher quality of workmanship that is possible only in a factory setting (Olson, 2010). Although, even with traditional, in-situ construction, designing to suit standard modules of products such as tiles and gypsum wallboard avoids waste from leftovers and gives a neat finished appearance (Moxon, 2012).

Figure 3.19 shows an example of a modular construction system. U-Build is a modular timber construction system developed by Studio Bark. The system relies on a flat pack kit that can be easily assembled into a variety of different building frames. To create a frame, the flatpack pieces are first slotted together to create hollow boxes, some of which have windows, and then combined to create the desired configuration, ranging from a single room to a large public building. The structures are designed to ensure they can be easily deconstructed or recycled, or moved to a new site and reassembled in the same or a different configuration. “The system is reusable, environmentally

Figure 3.22

U-Build, by Bark studio

responsible, and incredibly cost-efficient, with no quality sacrificed” explained the studio. Studio Bark wanted to make construction truly affordable and self-built, opening up the prospect of self-led construction to a greater proportion of the general public (Crook, 2019).

Figure 3.20 presents NO WÓDKA, a concept store designed by studio KONTENT. The store was designed in a way that allows the interior to be moved around and re-arranged, depending on events taking place inside. This has been possible thanks to the use of scaffoldings. Indeed, as scaffolding is a modular temporary structure there are no elements fixed to the walls and even two people can easily assemble it. The layout is therefore flexible and can be reconfigured and transformed into the exhibition or workshop space to fulfil the store profile. Moreover, when the set up will not be needed anymore, the structure can be disassembled and re-used (Davis, 2014). This case study also shows how very simple modular elements can be used for purposes different from the ones they were conceived for.

Figure 3.23

NO WÓDKA store, by KONTENT studio

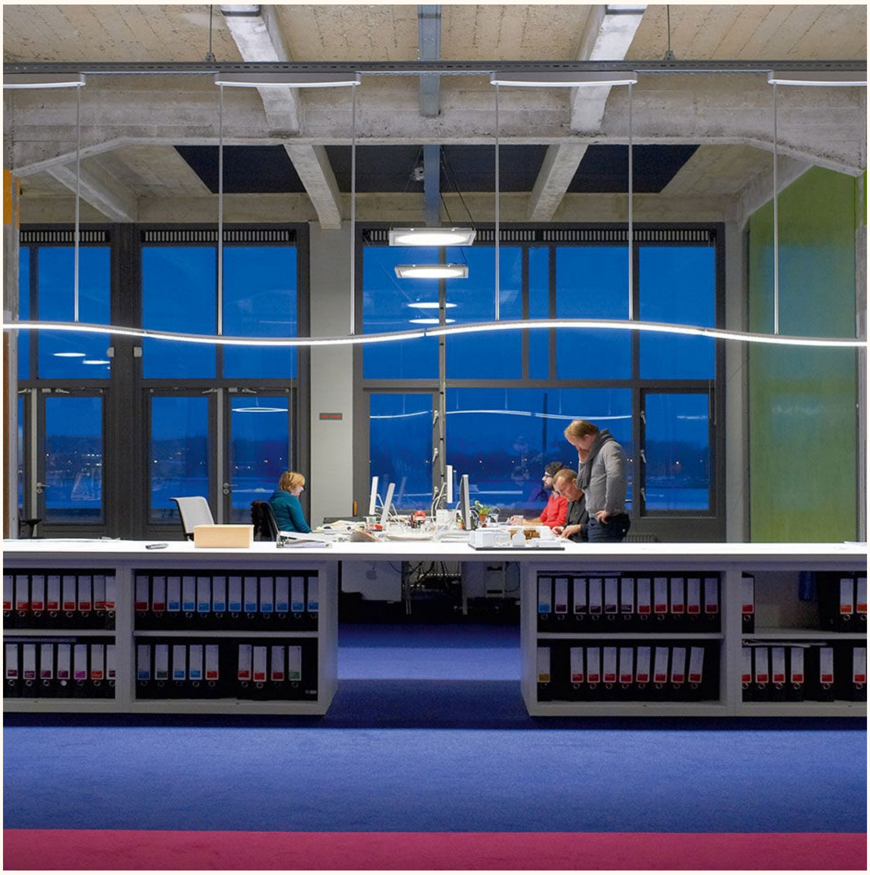
SHARING

Sharing can be interpreted in two main ways. Sharing spaces, in other word shared living, and “sharing”/renting products. Both foster a reduced need for materials. The former consists of people sharing some spaces, services and facilities while still having a private space, enabling users to consume less and therefore have a smaller environmental impact. The latter instead can be seen as the transformation from products to services, which enable manufacturers to retain the ownership of products while still delivering performance for their customers. Sharing, therefore, allows reducing per capita needs of products and resources.

Light as a service (Figure 3.5) by Signify, previously Pay- per- lux by Philips, is a business- to- business solution that provides lighting as a service. Customers do not own the lighting equipment instead, they rent it from Philips and pay a flat rate for an agreed amount of light that hits a given surface (measured in lux). The offer includes the design, installation, upgrading, repair and end-of-life collection of the lighting system. Philips retains ownership of the lighting equipment and thus has an interest in extending the product lifespan as much as possible.

Figure 3.24

Light as a service



3.3 How much is enough?

As explained in Chapter 1, today's growing population and consumption patterns are damaging the ecosystems that allow humanity to thrive. Consumption behaviours play indeed a crucial role within sustainability efforts. Interior designers can put into practice strategies to reduce material consumption but, in the end, is always the client that has the last word. Sadly, large parts of society see consumerism as a mean to a good life and believe that purchasing and owning the "right" possessions results in happiness (Hausen, 2018). However, several lines of research demonstrate that high consumption lifestyles and materialistic values are not a trustworthy path to well-being (Hausen, 2018). Owning the latest smart-phone, headphones or specific piece of clothing can make people feel happy, satisfied with their lives and accepted by a "community", but how long can these feelings last? Material possession gives users a hedonistic satisfaction, the kind of instant pleasures that lasts from a few minutes to a day. Instead, materially simpler ways of living with a focus on intrinsic values, have been suggested as contributing to profound happiness and fulfilment (Hausen, 2018) and thus providing a eudaimonic satisfaction, that is the life satisfaction we get from long-term goals, feeling of purpose or self-development (Boniwell, 2008).

The idea of leading simpler, less materialistic lives led to the birth of the minimalist lifestyle movement. Minimalists choose quality over quantity in each aspect of their life and therefore own only what is an absolute necessity. This, according to those following this lifestyle, allows to keep material life at the lowest and be more conscious of the things they bring into their lives and makes them happy in a eudaimonic term. A similar approach is that of the tiny house movement, an architectural and social movement that advocates living simply in small homes (Mitchel, 2009). By downsizing the space in which we live in we can, not only reduce the costs and "emissions" of a household, therefore being sustainable, but we can also embrace a simpler, more essential life. With an increase in cost and the environmental impact of homes, more and more people are reconsidering their housing situation.

Both movements show that it is possible to live with less and lead happier more sustainable lives. It is thus a matter of understanding how much is enough, or rather which levels of consumption and degree of simplicity can make us satisfied and happy.

4
Sustainability in practice

4.1 The steps to a environmentally sustainable interior

The designer' journey from idea to final proposal or realization is rarely a straightforward and evident path with clearly marked directions. It is rather a hazy and ill-defined route that designers undertake in different ways according to their attitude and approach to the project, the project itself, the client, the budget and many other factors. Developing a project is in fact a complex business that involves making difficult choices. Choices that could be even more intricate when sustainability is taken into account. The sustainability measures that designers have to evaluate and choose from are indeed several and professionals can easily feel overwhelmed by the complexity of the issue. Especially when they do not feel like they have the right competencies to decide and assess. However, professionals should acknowledge that even simple solutions and expedients can make the difference in an interior environmental impact (Moxon, 2012).

The following paragraphs are intended as simple guidelines to help young designers achieving more environmentally sustainable interiors. The steps outlined have a focus on materials and, thus, they are not comprehensive of all the possible sustainable measures. Furthermore, it must be noticed that they have been drawn up by the author of this dissertation according to her knowledge, hence they are only intended as a suggestion and a trigger to reflections. The reader might find some considerations obvious and maybe not eye-opening as he/she hoped, but what the author understood by working on this dissertation is that a project doesn't need to use the latest technology, material or system to be sustainable. Often the creativity and intelligence of a sustainability-minded designer and the straightforwardness and sincerity of the project can do the job.

To make the understanding of these stages more clear, these are accompanied by questions that designers could ask themselves and a case example that translates them into practice (Section 4.2)
The project developed in section 4.2 should be interpreted as an exercise, an experiment in which environmental sustainability was given the highest priority and all the possible sustainable strategies applicable have been employed.

A ANALYSIS OF THE PROJECT

As aforesaid, being informed is fundamental to ensure the sustainability of a project. Therefore, a virtuous way to start to favour the sustainability of a project is analysing its features.
One of the first concern of a designer should thus relate to the purpose of the project and the function it will absolve. This means understanding what the nature of the project is and why it is needed, what activities will happen in the space, when it will be used, by whom and what ambience it should create (Moxon, 2012). For example, a room meant for concentration (purpose), where users could work or study (function), will be different from one where to relax, and that same room will have different characteristics if it will be used by kids, young adults, parents or elderly (users). Different purposes, function and users affect the choices of colours, lighting, materials and construction methods, which all affect the sustainability of the design. For instance, by knowing that a space will have to serve multiple functions, the designer can envision furniture that facilitates this by being multifunctional and thus reduce the need for others.
Furthermore, designers should also estimate the lifetime of the interior and foresee a possible life-cycle. How long will the interior be required? What will happen to it after is no longer needed? What are the possible impacts of its ”end of life”? Looking at the life cycle helps designers seeing the bigger picture, recognizing the long-term environmental impacts, and empower them to make more environmentally responsible decisions.

Overall, having a deep understanding of the project's features enable designers to find solutions that are best for that specific case, avoid the specification of unnecessary materials and/or products and prevent the need for frequent repairs or refurbishments.

Questions to ask:

- What is the purpose?
- How it will function?
- Who are the users?
- How long it will last?

B ANALYSIS OF THE CONTEXT

The context can be social, economical, cultural, historical, even "architectural", and it is also thanks to its analysis that designers can understand what solutions are truly suited to the users and sustainable.
In this case, since the focus is on environmental sustainability, will mainly take into account the geographical context, to which sustainability is strongly related. Different regions have different histories, cultures and resources thus there is not a "one size fit all" solution. Solutions and materials that fit and are sustainable in a context might not be it in another. For example, using pine wood to build a pavement in Finland, where pine trees grow naturally and in large quantities, can be sustainable but, using the same wood for the same purpose in another country, where the material should be transported, might lead to the opposite. The same could be said about construction methods and assemblies. Consequently, analysing the context of a project is crucial to ensure it's sustainability. Examining the location of a project enables designers to know not only what materials are most suitable to the climate and thus will work better in the place, but also what materials are available in the area. Here, vernacular traditions have much to teach, because they evolved in response to climate, locally available materials, and cultural context to make buildings that would have a minimum environmental impact (Petrović, 2007).
Using local materials, avoid emissions and costs related to transportation, hence reduce the environmental impact of the project. Moreover, getting to know the location might suggest local industries or carpenters with which collaborate. Employing local manpower, industries, or merchants can diminish the emissions related to transport and the commuting time of workers.

Questions to ask:

- Where is the project located?
- What is the "architectural" context?
- What are the vernacular traditions?
- What are the local materials?

C RESEARCH OF SIMILAR PROJECTS

After getting informed about the project features and context, it is useful to research and study case studies of spaces that have some connection with the project that needs to be developed. To carry out this phase, information gathered in the previous ones come to help in narrowing down the research. Investigating case studies that have similar functions, users, sizes, stories or that are located in the same or comparable geographical area to the one of the project, can be of great help to designers. Indeed, these enable designers to have a more holistic view of different possibilities, learn and get inspired by other professionals and evaluate different solutions. Moreover, exploring case studies stimulates designers' critical thinking and hence enables rough sustainability evaluations. To favour this, professionals should approach case studies with curiosity, question the material use and their assembling, observe if practices of reuse or recycling have been applied and ponder what the life-cycle of the interior will be.

This phase is often carried out digitally on the web, where information retrieval is quicker and easier. However, real-life research can offer interesting and useful insight. Experiencing a space first hand might enable designers to have a better understanding of why some solutions were adopted, or what other expedients could have been used. Moreover, feeling a space with all the five senses can help in better defining the atmosphere and the material feelings that the designer wants to transmit.

Research case studies:
- Similar function /use
- Similar location
- Similar users
- Similar stories (e.g. renovation, new building)
- Simlar needs
- ...

D DEFINITION OF THE PROJECT

After all the information regarding the context and the project have been gathered, designers can better frame the project, define its boundaries and translate the requirements into a design. This means, first establishing the project objective, then outlining a list of constraints and priorities and later evaluate what strategies can be applied.
The objective consists of the scope, the final result. It could be that of designing a flexible studio apartment for an elderly couple, a gym for kids or temporary shop. The boundaries are instead delineated by the constraints the project has (e.g. hard to reach location, small space) and the features the project needs to have (e.g. suitable for big groups, easy disassembly). Defining these help the designer identifying a list of priorities and pinpointing which sustainable strategies could be applied. However, outlining the priorities is not always an easy task and compromise is thus often sought. The designer should indeed find the right match between the project's needs and the available resources and the constraints.

Questions to ask:
- What is the objective?
- Which are the constraints?
- What features the project must have?
- What are the priorities?
- Which sustainable strategies can be applied?

4.2 The steps in practice

This Section wills to make the steps previously outlined more clear by transposing them in a real-life case. Though, before doing so, a description of the project will be provided.

LIBRARY AND CO-WORKING IN PIANO AUDI

Piano Audi is a small hamlet in the Alps above Torino, where people from the city find retreat during the weekends or, most likely, in the summer and Christmas holidays. In these periods, a voluntary association of the village, Associazione Amici di Piano Audi, organises activities and events for people of all ages and takes care of some infrastructures (e.g. football field, volleyball court, the association headquarters). In the summer of 2019, a member of the association suggested creating a place where people could exchange and borrow books and magazines, and read. From there, the idea for a little library was born. In this preliminary idea, the library would have mainly hosted books regarding the history and nature of the valley, functioning as a central point to get to know Piano Audi and its surroundings.
Later on, with the surging of COVID-19, and more people working from remote, another idea came up between some younger members of the association. What if the library could also host a co-working in the future? Remote work and classes are likely to remain in place also after the pandemic thus, having a place where to work or study away from the city, but also outside of small mountain apartments or houses, could be useful for second homeowners who do not have access to the internet. Piano Audi is indeed not covered by either the telephone or internet signal.
The association thus concluded that it should be a place where users could learn more about the valley' past, and residents, tourists and second homeowners could study or work. This could also help or favour repopulating rural mountain areas which witnessed depopulation in the '50s. Moreover, Associazione Amici di Piano Audi would like the space to be a place for the community to meet, socialise and exchange stories and knowledge, a space where generations meet and do things together.

The place for realising this library/co-working has been offered by one of the members of the association and it consists of a small room located on the ground floor of a private two-storey building placed right in the middle of Piano Audi. The building used to be first a barn and later a partisans[10]' house. Still today, on the second Sunday of August, ANPI [11] goes to Piano Audi to remember the partisans who fought there and bring flowers to the house.

Note

[10] Partisans were those who were part of irregular armed formations that acted on the territory invaded by the Germans by exercising disturbance or guerrilla actions during the second World War.

[11] National Association of Italian Partisans

Figure 4.1
The building and the room where the library/co - working will be located

A ANALYSIS OF THE PROJECT

According to the project history and description, the space aims to be a library through which Piano Audi's territory and history are described and promoted, but also a co-working, a place where office worker and students can do their job.

What is the purpose?

- Create a collection of books, maps and documentaries that describe the valley's nature and history.
- Allow residents of the village, seasonal tourists and second homeowners to have access to the internet and escape the loneliness of studying or working at home.
- Encourage younger generations to live in mountain rural areas.

How it will function?

- The space will mainly function as a library, thus as a place where users will be able to borrow books, read and study, and as a co-working.
- Small meetings or presentations could also be arranged, and users could make themselves a cup of tea or coffee
- The space will be run by volunteers who will take care of opening and closing it and registering the loans. From the beginning of July to the end of August the space will be open from 8 to 12.30 and from 14.00 to 19.00. Whereas, in the other months, users will have to register on an online form and get the keys of the space form the nearby shop or the restaurant.

Who are the users?

- Second homeowners that are university students or young workers, willing to work or study remotely from Piano Audi but lacking internet in their homes (20-40 years old).
- Seasonal tourists, hikers and bikers interested in knowing more about the history and territory where Piano Audi is located (30-70 years old).
- Residents and association members, willing to organize small meetings or presentations.

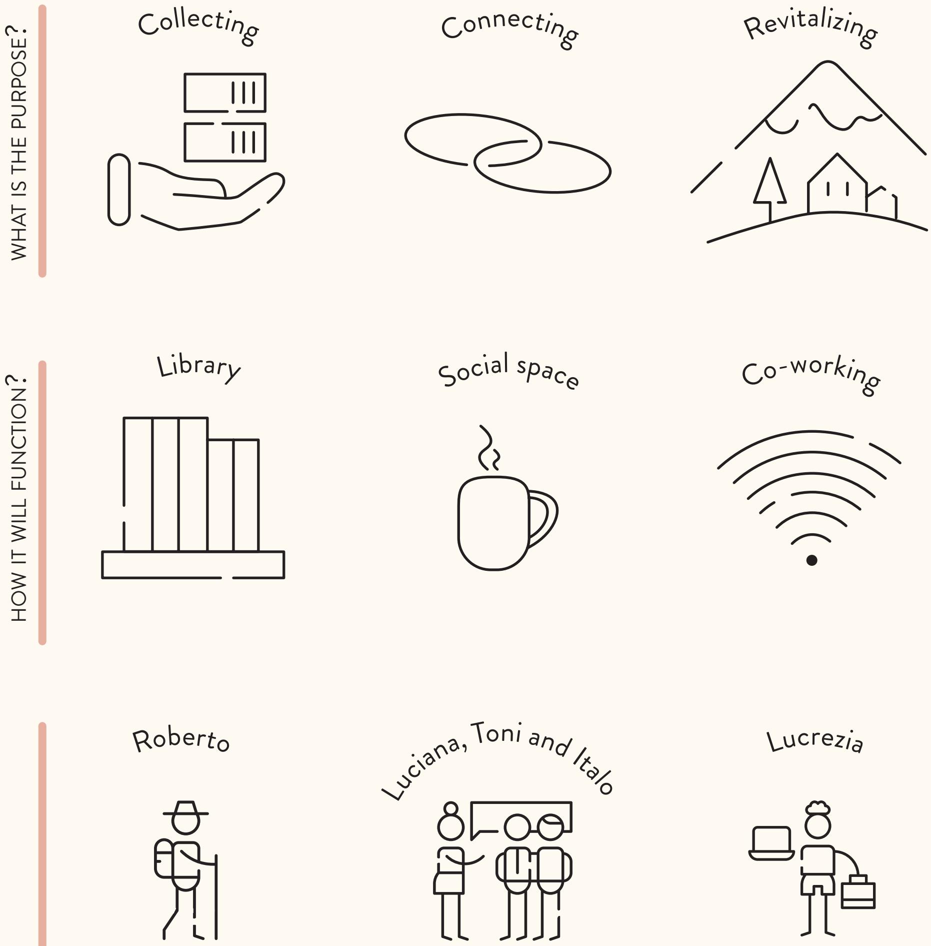
How long it will last?

- The space is expected to last many years but, since the building is private, the association wills the project to be the least invasive on the structure, flexible, modular and easy to disassemble. This would allow them to eventually dismantle the interior and reusing it in another location.

How is the space?

- The space is a room of around 18 square meters, located on the ground floor of a private two-storey building that used to be first a barn and later a house. The room, being surrounded by higher buildings and provided by only two small windows, is not very bright and, given the low vaulted ceilings, feels also quite small. Being an old house, the room features a sink and a fireplace.

Figure 4.2
Purpose, function and users



WHO ARE THE USERS?

Roberto

65 years old
Retired employee

Roberto lives in Turin but goes to Piano Audi to hike in the weekends. He would visit the library to discover new trails and learn about the valley.

Luciana, Toni and Italo

55-80 years old
Workers or retired

Luciana, Toni and Italo are “executive members” of Associazione Amici di Piano Audi and they would use the library to meet and discuss the activities of the association.

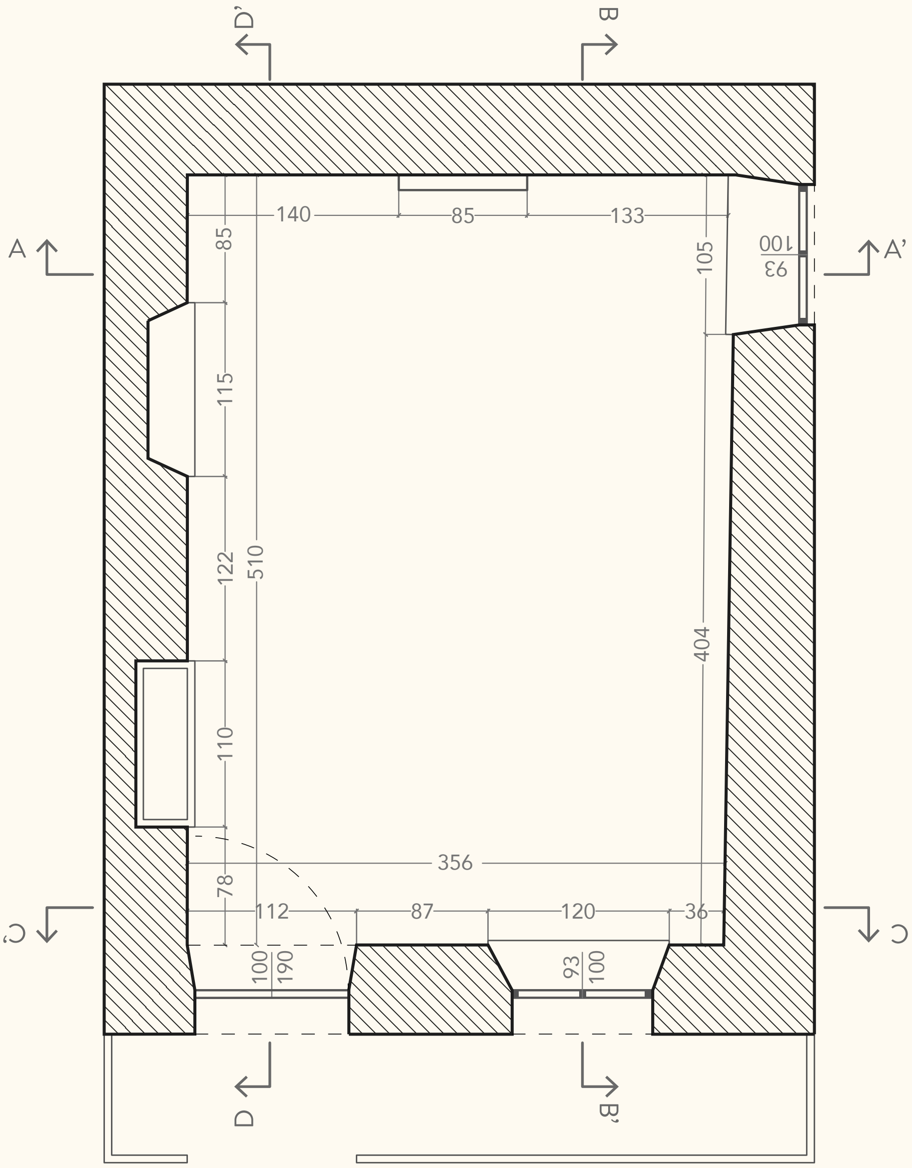
Lucrezia

20 years old
University student

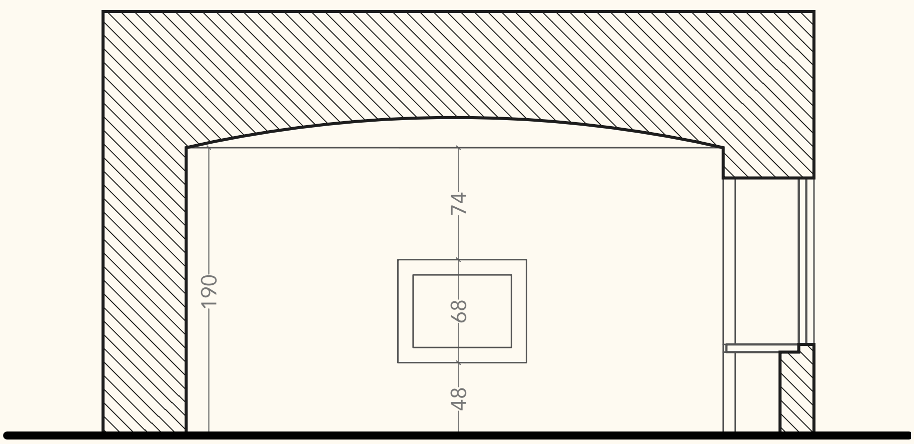
Lucrezia’s grandparents have a house in Piano Audi. She enjoys staying there but she doesn’t have internet. She would stay in the library to study and eventually follow online lectures. Also her dad, Claudio, would use the space for working.

Figure 4.3

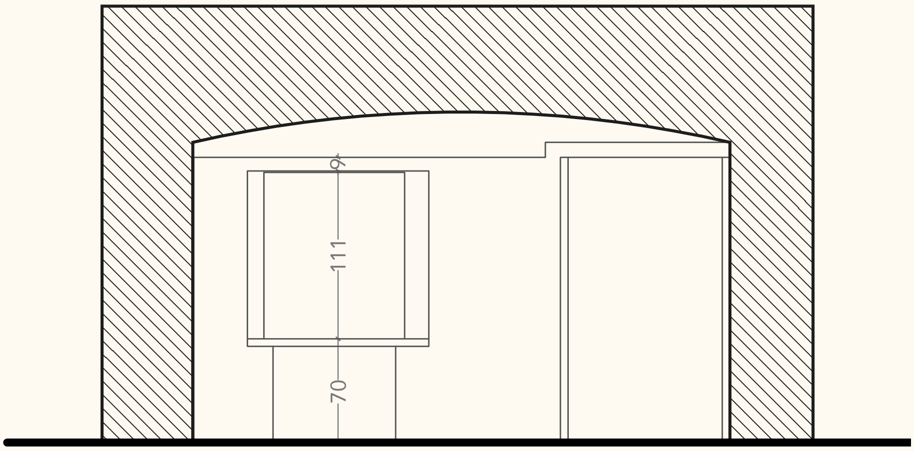
Technical drawings, scale 1:50



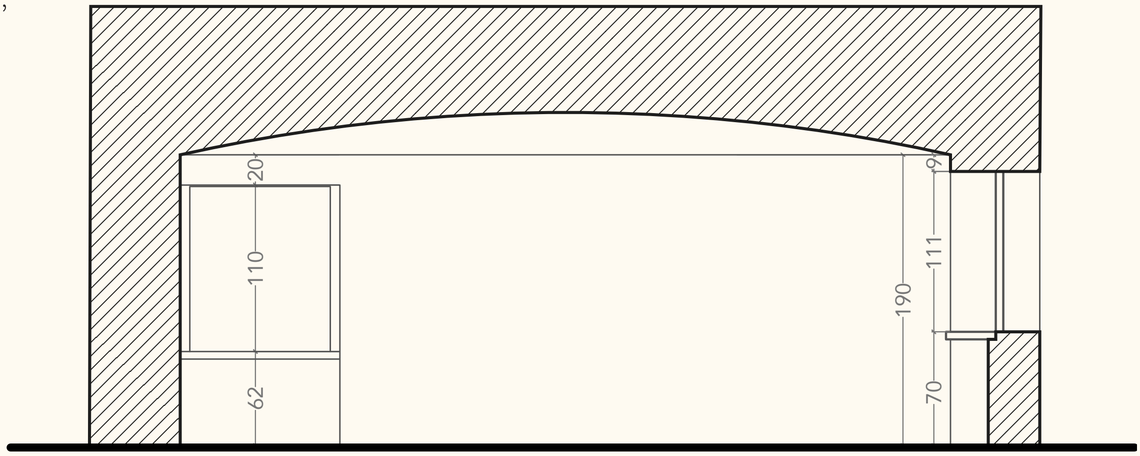
AA'



CC’



BB’



DD’

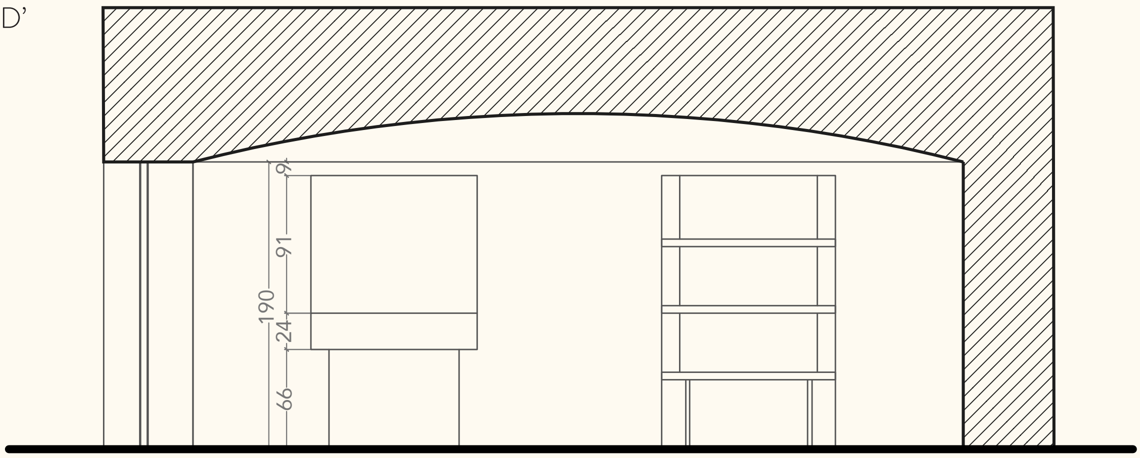
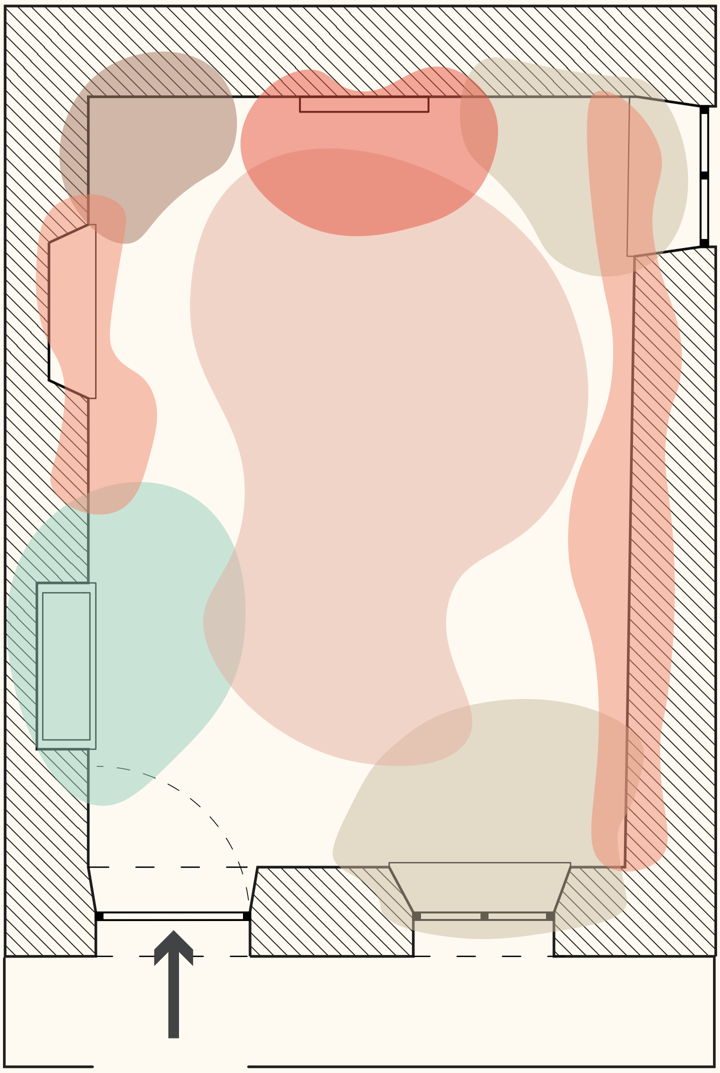


Figure 4.4

Area analysis and definition of functional areas



Entrance

Take a break
After entering the space, on the left, there is a quite long sink. The area around it could become a spot for making a cup of coffee or tea. Being right after the entrance, it could also be the place where to keep a record of what book have been borrowed, who entered the space, etc...

Library
The areas along the walls, less illuminated by direct natural light, could host the **bookcases**. This would also allow natural light coming from the two small windows to better lighten the room and to give more "breath" to the space.

Call booth
This corner is the quietest area of the room and, because of its configuration, it could be easily divided form the rest of the room to provide the privacy necessary for a short **video call**.

Hot spot
The small volume "attached" to the wall is a fireplace. The surrounding area will thus be the warmest of the room when the fireplace is on. It could be a nice and cosy spot where to **read**.

Reading nooks
These areas, being located next to the windows, are well illuminated by natural light and have views on the outside. They could thus be dedicated to **reading or studying** on comfortable **armchairs or sofas.**

Co-Working
Desks, chairs and sofas where users could work and study could occupy the centre of the room. However, since the space is limited, has to accommodate different needs and the apertures which provide natural light are small, it would be better if this area would be very flexible, allowing various configurations.

B ANALYSIS OF THE CONTEXT

In this case, a brief examination of the socio-economical and historical context has been carried out because it was fundamental to better frame the work.

Where is the project located?

- Piano Audi, hamlet of Corio, Torino, Italy.
  Piano Audi is a small village 870 meters above the sea level, located on a sort of plateau in the Alps surrounded by forests.

What is the socio-economical context?

- The village is inhabited by about 30 people all year long and around 100 or more during the summer. Most of these 30 residents are retired carpenters, construction workers, farmers and merchant who always lived there and learned how to arrange them self for things of all sorts. It is also thanks to their knowledge, time, and work that many “infrastructures”, such as the association headquarters, a small football field and a volleyball court, have been kept in good conditions. These are mainly used during the summer or on the weekends when many people from Torino come to Piano Audi. The hamlet, during the ‘60s and ‘80s, hosted a great number of holidaymakers who swarmed into the valley during the summer. In the past decades the numbers of seasonal tourists diminished greatly but recently, thanks to the work of some voluntary associations, the whole valley is witnessing a renaissance. More and more people are visiting the area for hiking, cycling, trail running and other sorts of mountain outdoor activities. This is greatly benefiting both farmers and commercial activities.
  In Piano Audi, there are two commercial activities: a bar/restaurant, and a small shop. Both, since the village is not covered by the telephone signal, decided to provide their costumers with free Wi-Fi.

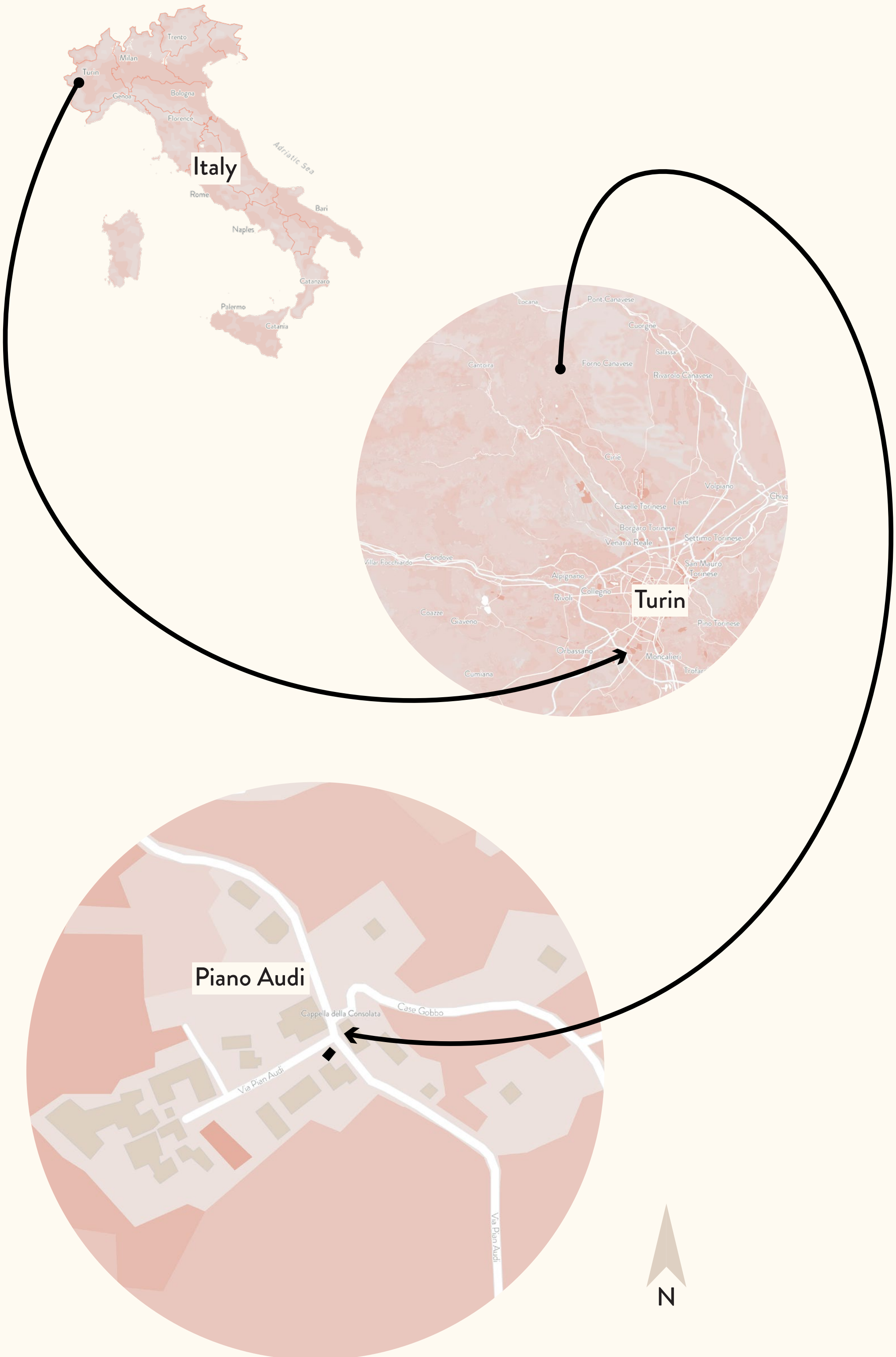
What is the “architectural” context?

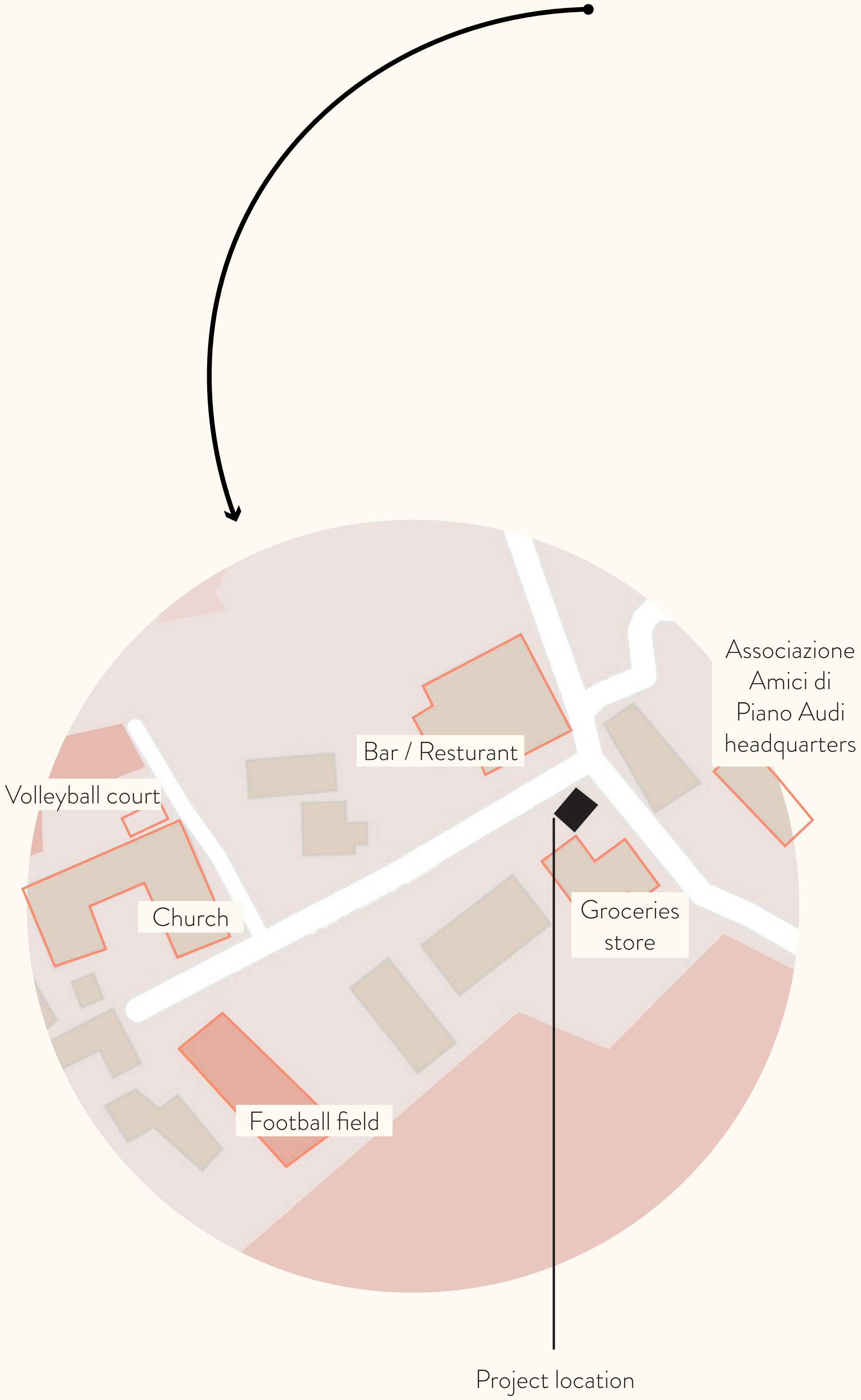
- Traditional houses are still present in the older part of the village and are mainly made of stone coming from nearby mines and wood. However, new houses were built during the economic boom of the ’60s without taking into account the landscape and the traditional architectural style, ruining the beauty of the place. These new constructions are mainly residential multi-storey buildings build to host the great numbers of tourists of that time.

What are the local materials?

- Piano Audi is surrounded by forests of beech, chestnut and walnut, thus wood is one of the main local materials.
  The other very common material is stone. Several were indeed the mines Mica scists and gneiss which provided the material not only for walls but also for balconies and roof tiles.

Figure 4.5
Location of the project




Associazione Amici di Piano Audi headquarters
Bar / Resturant
Volleyball court
Church
Groceries store
Football field
Project location

C RESEARCH OF SIMILAR PROJECTS

Researching case studies for this project has been enriching and fascinating because the author had the chance to visit and explore some of the most important libraries of Helsinki, the capital of a country that highly value and use library, Finland. In Finland, according to the European Bureau of Library, Information and Documentation Association, there are 979 public libraries, that is, roughly one for every 5,400 inhabitants (almost double with respect, for example, to neighbouring Denmark or Italy, and 10 times greater than Portugal, where there's one library for every 54,000 inhabitants) (Sommariva, 2018). In Finland, probably because it is vast nation with a low population rate and also a small linguistic community, libraries have always stood for access to information and entrance into the community. Moreover, Finnish law on public libraries from 2017 calls them symbols of active citizenship, democracy and freedom of expression (Sommariva, 2018). Indeed, the most recent libraries invites people of all ages to spend time there, to socialise, to relax and offer more than free books to borrow. These libraries are somehow what the library/co-working in Piano Audi aims to be and their study has therefore been very inspiring.

Similar function /use

- National Library of Finland, Carl Ludvig Engel, 1840
- Rikhardinkatu Library, Carl Theodor Höijer, 1882
- Helsinki University Library, Anttinen Oiva Architects, 2012
- Oodi Library, Ala Architects, 2018

Other case studies which were similar for location have been examined to see what strategies can be applied in an Alpine context.

Similar location

- On Mountain Hut, On, 2019
- SkinOver Reed, University of Stuggart, 2020
- MeCri Museum, Studio Inches, 2012

Examples of spaces with comparable needs have also been explored to find inspiration.

Similar needs

- Tense, Panter & Tourron, 2019
- All I Own House, PKMN Architecture, 2014
- Candy Cubicle, Sabine Marcelis, 2020

Similar function

RIKHARDINKATU LIBRARY

CARL THEODOR HÖIJER
HELSINKI
1882

Rikhardinkatu library was the first building in Finland designed for library use. Specifically, as a public library. Opened in 1882, it was the place where working classes were offered the chance to improve themselves and spend their time off in civilised surroundings (Navi Finnish Architecture, 2020). The Neo-Renaissance building was designed by architect Carl Theodor Höijer but in more recent years an extension has been built. The library features cosy reading corners, a well-lit reading hall, numerous workspaces and impressive views over the roofs of the city. The collection includes not only books but also art (Vartola, 2018).
The main materials used are linoleum for the floors and wood for the bookcases. Colours are many and vary from white and cream to pastel greens and beige.

Figure 4.6
Rikhardinkatu Library, new addition, main staircase

Considerations:

- It was built as a library but it feels like a home. Every room is quite unique, in terms of colours and furniture, there are artworks hanged in some corridors and plants on tables and bookshelves. This gives character to the spaces but makes the whole library less uniform in style.
- It is clear that the library has adapted to the passing of time but the changes made were not always well integrated with the original architecture. It misses some sort of coherence.
- The whole library is a disorganised mix of materials, furniture and systems, thus making considerations regarding its sustainability is difficult.

Figure 4.7

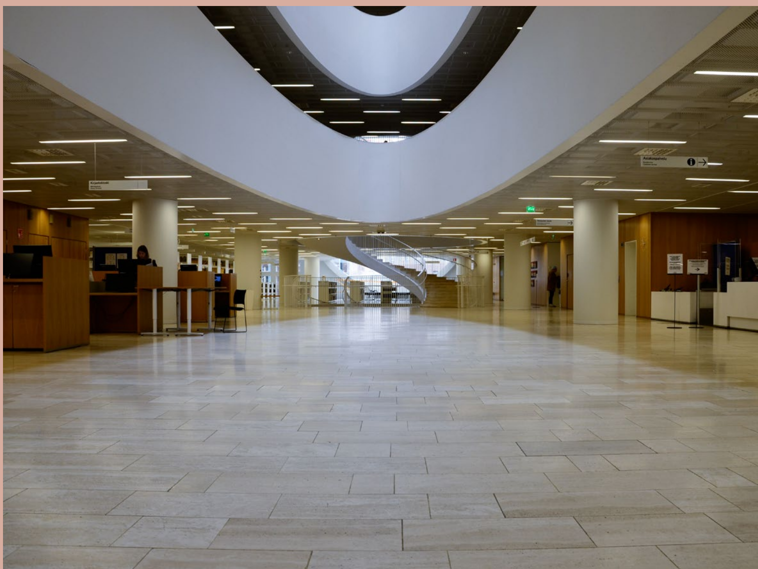
Rikhardinkatu Library, reading hall at the second floor

HELSINKI UNIVERSITY LIBRARY

ANTTINEN OIVA ARCHITECTS
HELSINKI
2012

The main library of the University of Helsinki, also known as *Kaisa-talo*, house of books, is the biggest scholarly library in Finland. The building, designed by Anttinen Oiva Architects, features seven above-ground floors connected by a massive curved void that can be admired from the entrance on Fabianinkatu (Kivistö, 2020). The floor is made of travertine at the entrance and of dark brown linoleum on the other floors. The walls are all white except for those next to the elevators or smaller rooms, which are covered with a boiserie. The main colours are white and grey, which are counterbalanced by the light brown of the wood and the vivid colours of some armchairs. The ceilings are suspended and are made of a white perforated wire mesh.

Figure 4.8
Kaisa Talo, entrance



Considerations:

- The interiors are very bright and are characterised by a coherent and balanced style.
- Some of the materials used have consistent impacts on the environment but their use is understandable considering it is a long-lasting project.
- This covers the systems but does not hide them completely giving the feeling that the ceiling is higher and making the maintenance easier.
- There are around a thousand workspaces in the open reading areas, quiet reading rooms, group workspaces and rest areas. Having different working areas allows for greater efficiency of the space used.

Figure 4.9

Kaisa Talo, first floor

OODI HELSINKI CENTRAL LIBRARY

ALA ARCHITECTS
HELSINKI
2018

Oodi, Helsinki's new central library, is more than a common library and it thus represents the experimentation within Finnish libraries to offer new services in addition to loaning books. Organised on three floors Oodi features a café, restaurant, public balcony, movie theatre, audio-visual recording studios and a maker space. The last floor, where the actual library is located, has a peaceful open-plan reading room that has been nicknamed "book heaven". This area has been built using local materials and with local climate conditions in mind. Wood is indeed a ubiquitous material in ALA's library and, together with glass, is almost everywhere (ALA Architects, 2020). Oakwood pavements are sometimes covered by colourful carpets which contrast beautifully with the bookshelves and the wavy white-coloured ceiling punctuated by circular skylights.

Figure 4.10
Oodi, book heaven

Considerations:

- The space is very bright, and it has a comfortable and relaxing atmosphere. It is not only a place to read and study but also and foremost a place to enjoy. It can be defined as "extra".
- Space is characterised by visual permeability. The books are indeed organised on low height white bookshelves, which allow looking around while searching for a book, and the balustrades are made of steel nets, which do not block the view.
- The great amount of natural light and the high visual permeability allow reduced use of artificial light.
- The presence of a few book and the open-plan layout of "book heaven", allows for possible reuse or reorganization of the space in the future.

Figure 4.11
Oodi, book heaven

Similar location

ON MOUNTAIN HUT

ON
PIZ LUNGHIN
2019

This small hut has been built by the footwear brand "On", to mark the launch of its latest collection including its first hiking shoe. The cabin has been designed with an entirely minimalist ethos, and with great care for the environment. Inside, the simple hut is finished almost entirely with plywood, while outside has been clad in reflective corrugated material so that it has a minimal visual impact on its alpine location. According to On art director Thilo Alex Brunner the materials were meticulously selected to be 100 per cent sustainable and suitable for the alpine setting, making the cabin a zero-waste mountain hut. The hut is also powered by energy from solar panels and uses natural rainwater. This was achieved by installing a unique roof fixture that could collect and filter rainwater for use, along with water collected and filtered from mountain streams (Ravenscroft, 2019).

Figure 4.12
Mountain Hut,

Considerations:

- The main materials used are two long-lasting materials, wood and metal. Wood is an appropriate material for the context because it's local and well suits the project requirements. Metal is not local but, being reflective, it fulfils the need of making the hut blending in the context.
- Very few materials have been used but, since the project is temporary, it would have been good if they have been reused.
- The inside, being made of only one material, looks very neat, modern and minimal but it might get ruined easily, especially in the entrance and on the furniture.

Figure 4.13

Mountain Hut, interiors

SKINOVER REED

UNIVERSITY OF STUGGART
VORARLBERG
2020

SkinOver Reed is a thatched hut located in the Austrian Alps, designed by the University of Stuttgar for the German Alpine Club (DAV) as an experiment to test the capabilities of thatch as an alternative building material to typical Alpine structures. The materials commonly used are either stone, concrete, metal or wood. DAV asked for an alternative, a renewable material that could meet their standards and especially their climate goals. Thatch is a sustainable, renewable, carbon-neutral resource that seems to be a perfect alternative renewable material for the building envelope: rapid growth, short process chain with low energy demand and emissions, perfect life cycle, no pollutants, and proved over generations. Moreover, at the end of life, reed is compostable and closes the material life cycle (Carlson, 2020).

Figure 4.14
SkinOver Reed, view from outside

Considerations:

- Thatch is a traditional and environmentally-friendly way of building houses, but it has never been used in an Alpine context. This can be thus considered an innovation and a transfer of a material from one context to another.
- At the end of its life cycle, the hut could be possibly composted
- Thatch, according to the architects, allows for very three-dimensional design, almost analogue to concrete.
- Reed was used for both the facade and roof cladding of the hut, making it insulated and waterproof.
- The hut was built by craftsmen and students. Collaboration and participation are elements that improve the care for the place.

Figure 4.15

SkinOver Reed, detail of a wall

MECRI MUSEUM

STUDIO INCHES
MINUSIO
2012

Studio Inches added a gallery to the Alpine art museum *MeCri*, dedicated to late Swiss artist and archaeologist Aldo Crivelli. This extension has been described by the architect Matteo Inches as a “dialogue between materiality and modern architectural expression”. The building has rough granite walls and a steeply angled concrete roof. These materials are intended to complement the whitewashed stone walls of the nearby old house, as well as the more rustic aesthetic of other buildings in the Alpine village. Indeed, the stone used is local and the concrete has been washed in order to create a finishing that integrates with the context.
The interior is very minimal with windows deliberately small to create more flexibility for hanging artworks (Frearson, 2020)

Figure 4.16
MeCri Museum, outside

Considerations:

- It is a long-lasting project thus the use of concrete and stone, which both have considerable impacts on the environment, shouldn't be demonized. However, the architect could have evaluated alternatives to them, especially concrete, which wasn't a local material and has been used greatly.
- The materials used and their finishes have been carefully selected to make the building fit well in the context but also make it modern. This is a difficult and particularly important challenge.
- Leaving the inside minimal and flexible allows the space to, not only adapt to different exhibitions but also to fulfil multiple purposes in the future.

Figure 4.17

MeCri Museum, interior

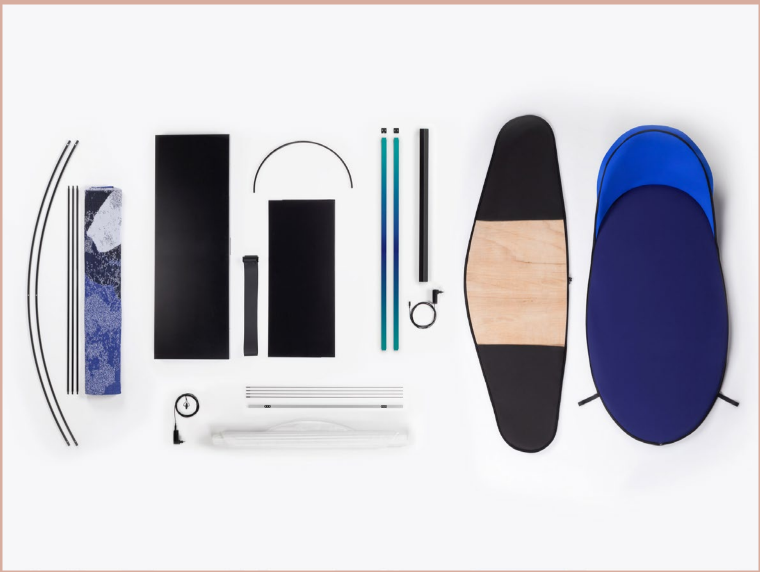
Similar needs

TENSE

PANTER & TOURRON STUDIO
MILANO DESIGN WEEK
2019

Panter & Tourron's studio designed a set of flat-packed furniture essentials called *Tense*. The collection comprises a table, chair, pendant light, wall light and screens that can be used to divide a space. All the pieces are extremely lightweight. All together they weigh less than 20 kilograms and hold their shape solely using tensile strength. Moreover, each of the five items is easy to transport either flat or in a tube, and can be assembled without the need for parts or tools, "allowing one to recreate and rebuild a home anywhere in a few simple steps".The five-piece collection can be thus easily assembled anywhere and is a research project looking at innovative furniture solutions for a globally mobile generation.
(Pownall, 2020)

Figure 4.18
Tense collection, before assembling



Considerations:

- An innovative project in the furniture industry
- All the pieces allow for easy reuse, disassembly and recycling.
- Being lightweight makes their transportation costs and emissions lower than other furniture systems
- The material used are various and some, like metal and plastic, also have considerable impacts, but the way in which they are assembled enable an easy disassembly and thus easy recycling. Plus, they are durable and therefore ensure the object a long lifetime

Figure 4.19

Tense collection, assembled

ALL I OWN HOUSE

PKMN ARCHITECTURES
MADRID
2014

In *All I Own House* PKMN Architectures designed custom-made wooden units, conceived as "suspended, mobile, and transformable containers" to allow easy reconfiguration of a small space, and serve the client's diverse set of needs. The compartments, providing a total storage volume of 11,27 cubic meters, serve as bookshelves and storage for footwear, household goods, cleaning supplies, clothes, a kitchen counter, and a bed. Each unit weighs between 500 and 800 kg when completely filled, yet thanks to the use of simple industrial rails can easily be moved with one hand. This transformer house concept for a unique, compact site, PKMN says, allows the client "to adapt the whole house according to specific needs for the use of space at the time, enabling infinite homes within a house" (Quddus, 2014).

Figure 4.20
All I own house

Considerations:

- The highly flexible layout allows having all the functions needed in less square meters than the ones necessary in a traditional one.
- The material used for the cabinets is oriented strand board (OSB), which was probably chosen for its strength and to manage budget constraints. However, OSB is made from layers of compressed wood flakes and often has glues that off-gas VOC.
- The system that enables the wooden containers to move is made of quite a simple industrial railings, requiring no energy to function.

Figure 4.21

All I own house

CANDY CUBICLE

SABINE MARCELIS
LONDON
2020

Candy Cubicle, the project by Sabine Marcelis for the Design Museum's Connected project, is like a magic box. On the outside, it looks like a simple wooden box but, if opened, a bright office set up comes out. The pale wooden shell sits on hidden wheels and can be opened along a central axis, transforming it from a block into an L-shaped desk setup. This offers storage for books and documents on one side and space for a computer on the other. When not in use everything can be hidden inside, and moved around, leaving the space neat and organised. Marcelis created the piece in response to a brief by the Design Museum and the American Hardwood Export Council (AHEC), which called for nine international designers to develop a wooden desk and chair set up to suit their "new ways of working from and living at home" during the lockdown (Hahn,2020)

Figure 4.22
Candy Cubicle closed

Considerations:

- The desk is something that can be transformed from working mode and then back into hiding mode, allowing different configurations depending on the user's needs.
- It is entirely made in maple wood sourced from a sustainably managed forest (except for the hardware and wheels) making it suitable for eventual recycling.
- The wood was sourced and shipped in from the US. AHEC's European director claimed that "the carbon stored in the wood during growth is much greater than all the emissions associated with harvesting, processing and transport" but using wood coming from a country closer to the UK would have been a better choice.

Figure 4.23

Candy Cubicle open

D DEFINITION OF THE PROJECT

According to the project' characteristics that emerged from the analysis, it is possible to better frame the project. Thus, define the objective, determine which are the priorities, identify the main constrains, and then consider which sustainable strategies (Chapter 3) can be applied.

What is the objective?
- The objective is to design a library that could also function as a co-working and could become a space for social interaction.

Which are the constrains?
- Rural mountain area
- Small space with only two windows and low ceiling, thus quite dark
- Volunteers work

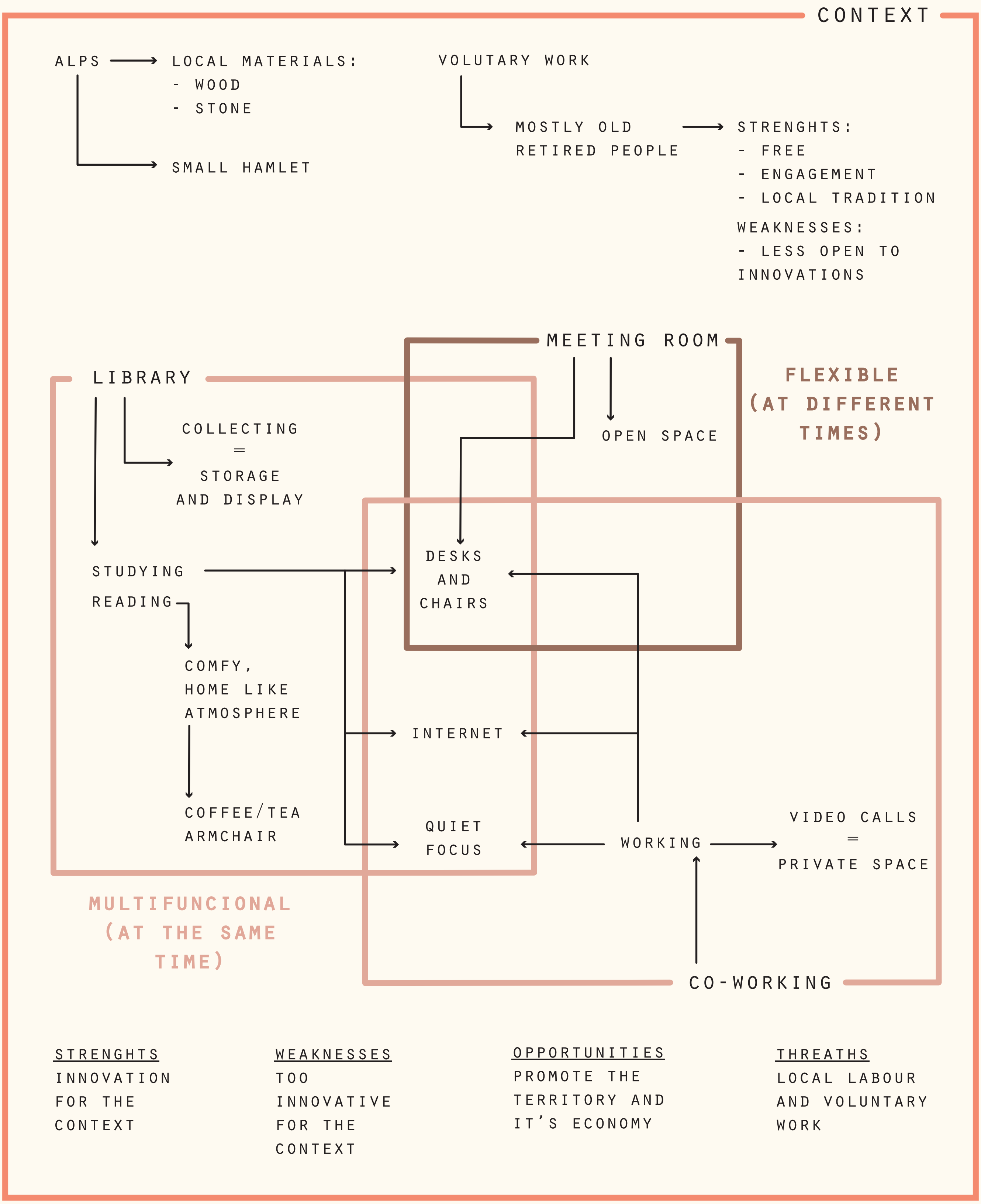
What are the features the project must have?
- Clear categorization of the books through an effective storing system
- Areas for working and studying (desk, chairs, sofas)
- Multiple possible layout
- Welcoming atmosphere

What are the priorities?
- Safety and comfort
- Environmental sustainability
- Aesthetic

Which sustainable strategies can be applied?
- Simplicity: the space should last many years thus it shouldn't look or feel outdated after a short time.
- Modularity: the space is private thus the furniture should be modular and of standard sizes so that it could be eventually disassembled and reused in another location.
- Flexibility: the space should accommodate a the needs of users who will read, study or work but, eventually, also group meetings or presentations
- Multifunctionality: the space is limited and the function requested several thus would be advantageous to favour the use of multifunctional furniture and layouts.

Figure 4.24

Table of the project' features, needs and characteristics



4.2 Biblioteca R / R library

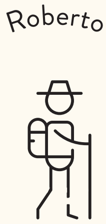
R library aims to be a place for stories to be collected, learned and heard but also created. A place strongly embedded in the present but also deeply in contact with the past, that keeps track of the history of the valley and the transformations she witnessed (resistance). A space that constantly changes with its users and their needs and adapts to the passage of time (resilience). An interior that cares for the context in which is it located (responsible). Form here the name, R library, a library that is resistant, resilient and responsible. The concept developed for R library is thus related to the ideas of adaptation and metamorphosis.

Figure 4.25
Concept

The space itself but also the furniture should be able to adapt, change and quickly transform into something else. The bookcase becomes a desk, the shelf becomes partition and the sofa become a table.

A highly flexible layout, that adjusts to the users and enables multiple configurations is would also be needed. The plans of the following pages (figure 4.27) show possible layouts and utilizations flows of 4 personas, Roberto Lucrezia, her dad Claudio, and Luciana, Toni and Italo.

Figure 4.26
Personas

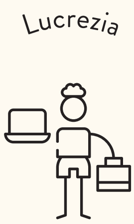


65 years old
Retired employee

Roberto lives in Turin but goes to Piano Audi to hike in the weekends. He would visit the library to discover new trails and learn about the valley.

55-80 years old
Workers or retired

Luciana, Toni and Italo are “executive members” of Associazione Amici di Piano Audi, and they would use the library to meet and discuss the activities of the association.



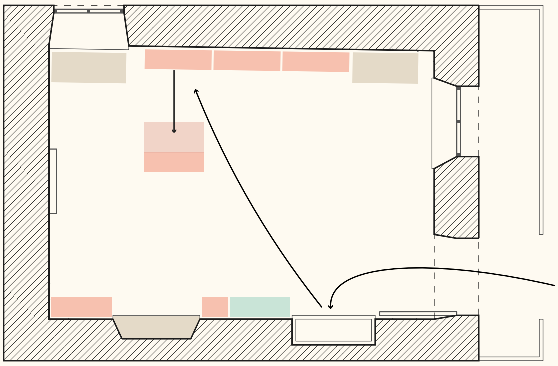
20 years old
University student

Lucrezia’s grandparents have a house in Piano Audi. She enjoys staying there, but she doesn’t have internet. She would use the library to study and eventually follow online lectures. Her dad, Claudio, would use the space too for working.

Figure 4.27

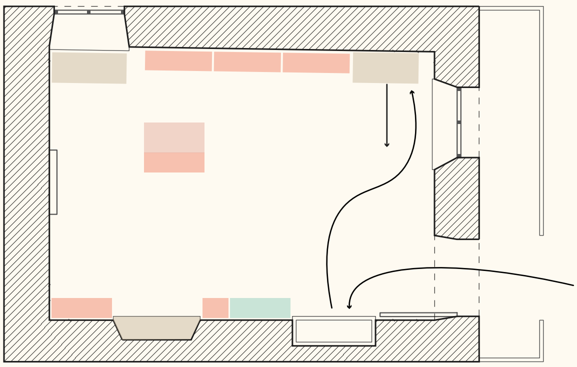
Layout transformations and utilization flows

- Utilization flows
- Bookcases
- Working tables
- Sofas or armchairs
- Private pod for video calls
- Coffee table and chairs



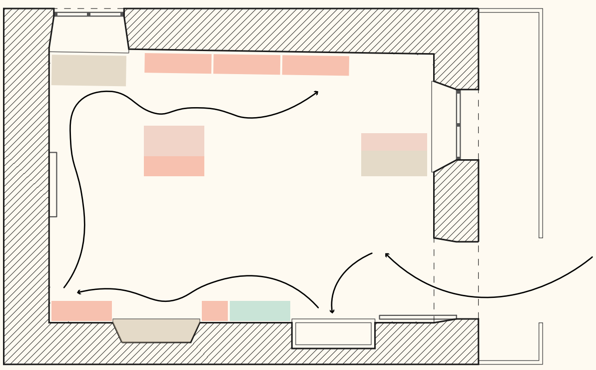
8.30

Lucrezia goes to the library to prepare an exam. She enters, washes her hands, pulls out a working table and starts studying.



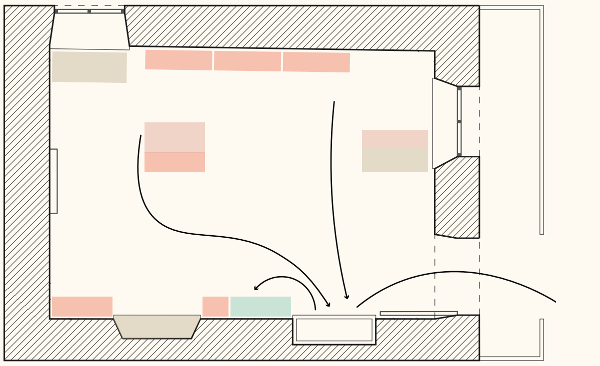
9.00

Soon after also Claudio arrives to do some work. He washes his hands, moves the couch and folds down the table to work.



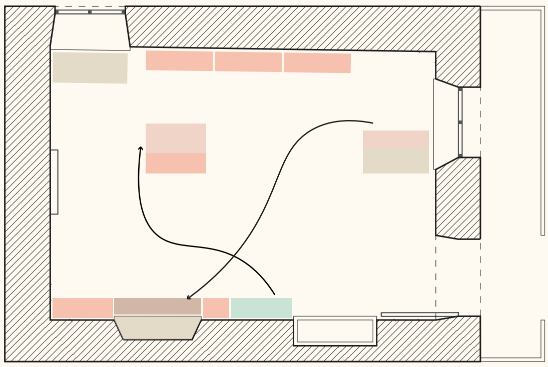
11.00

After a while Roberto enters the library to find a book about the Italian resistance movement he wishes to borrow. He finds it and calls Lucrezia.



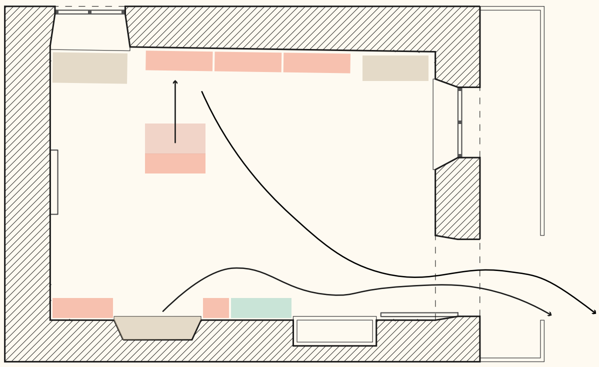
11.15

Lucrezia reaches the cabinet under the sink and takes out the documents to register the loan. Then Roberto leaves and she make herself a cup of coffee.



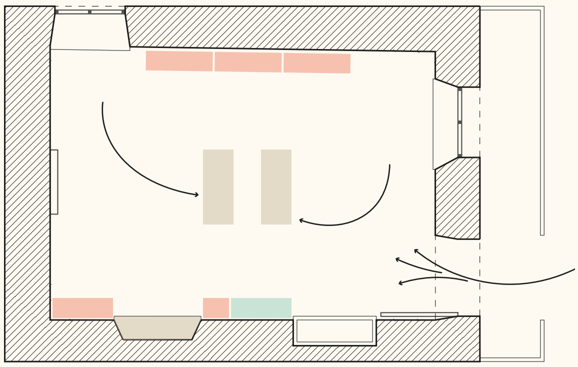
11.30

Claudio suddenly remembers he has a video call with his colleagues. He leaves the desk and pulls out a "private pod". Lucrezia goes back to her desk.



12.30

Lucrezia and Claudio put away the desk and the "call booth" and leave.



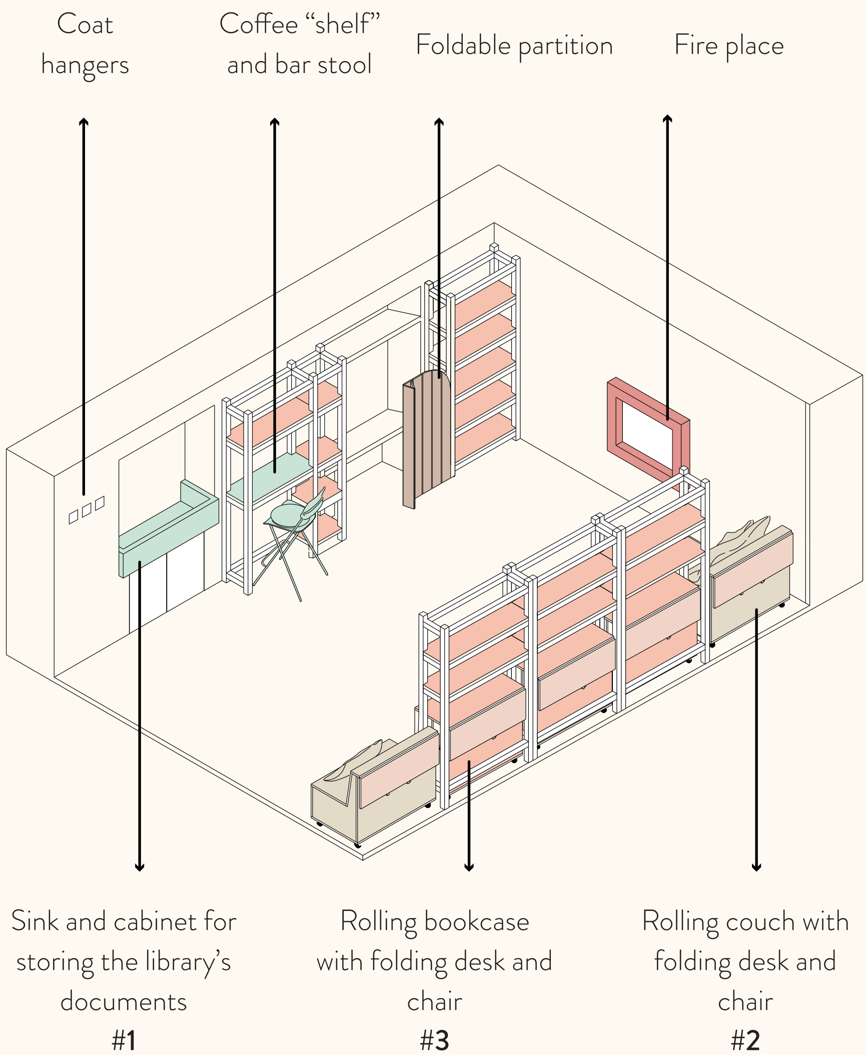
12.30

At the same time Luciana, Toni and Italo arrive. They set up the couches and start a small meeting.

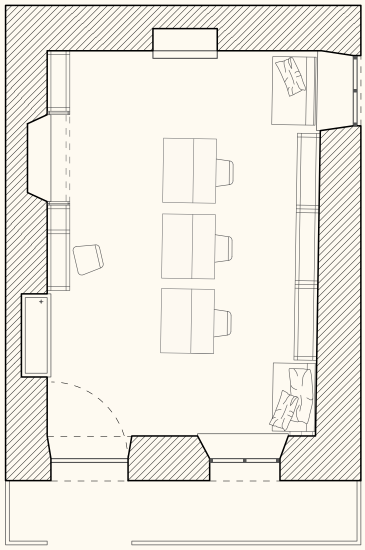
LAYOUT

The previously made considerations lead to the development of the layout showed in figure 4.28. Sustainability has been the main driver of many choices, but there are also three other main "concepts" which had a strong influence and guided the design: multifunctionality, flexibility, and disassembly. As a result, space has been designed with great attention to the materials and assembling methods, and care for the various needs of the different users.
This layout, with all the furniture aligned on the walls and taken out only when needed, allow creating several configurations and hosting diverse functions. Moreover, having more free space at the centre favour the diffusion of natural light, spreading warmth from the fireplace and helps in making this small space feel larger and less upsetting.

Figure 4.28
Isometric axonometry



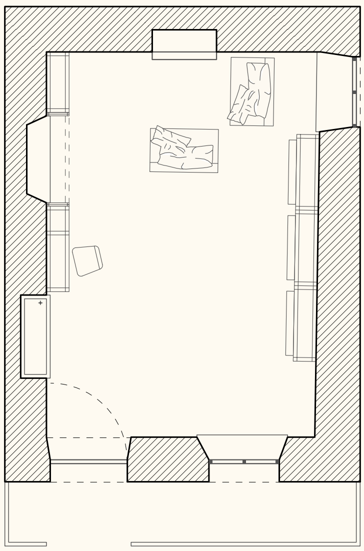
STUDYING



The 3 rolling bookcases are pulled out, the desk unfolded and the chair is taken out.

In this configuration, users would be studying or working.

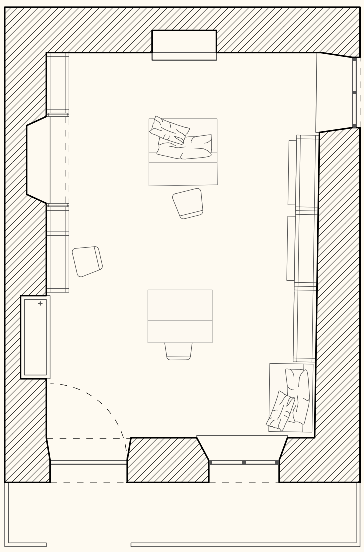
CHATTING



The rolling couches have been moved next to the fireplace.

This layout might occur in the wintertime to enjoy the warmth of the fire while chatting.

MIX



The rolling couches have been moved to the centre of the room and the desk unfolded.

This arrangement might occur when the space is used by users who are reading, relaxing, studying or working.

SYSTEMS

Consequently to the layout, the systems have been designed. The ones taken into account, in this case, include the lighting and heating systems.
Heating will be provided by a fireplace located on the ending wall of the room. An open fireplace was already present but, not being very safe, it will be replaced by a closed one. Considering the space dimensions it will provide enough heat for the whole room.
General illumination will be provided by two pendant lights on the vault while accent illumination will be given by led strips. Additionally, desk lights will be placed on the desk.

Sockets will be placed as shown in figure 4.29

Figure 4.29
Lighting system

× Ceiling light point

Socket

Switch with double command
1. General illumination
2. Accent illumination

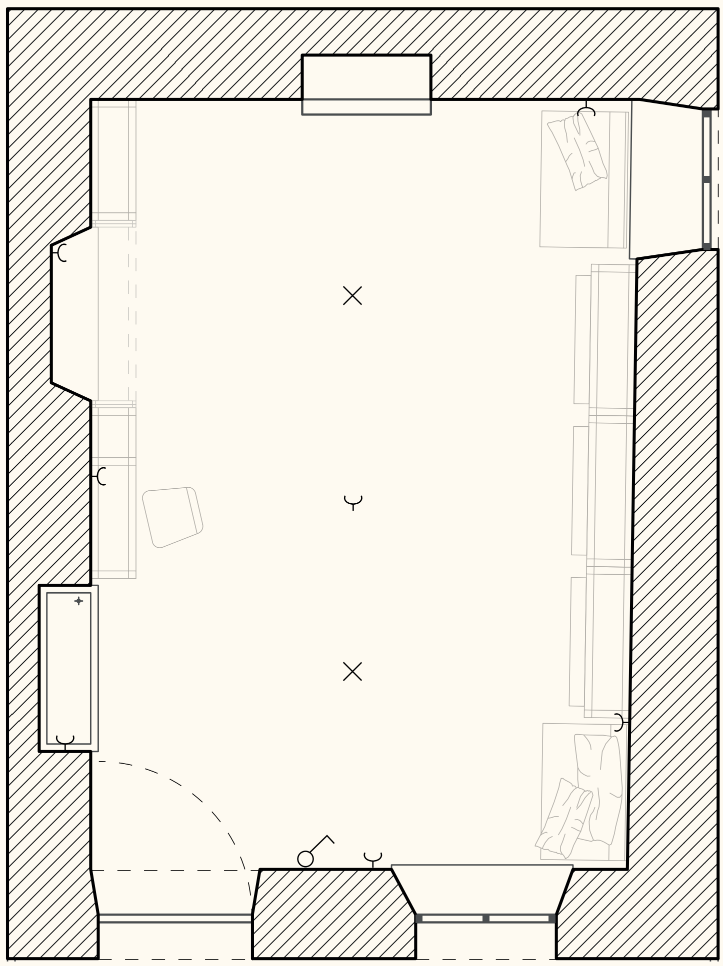


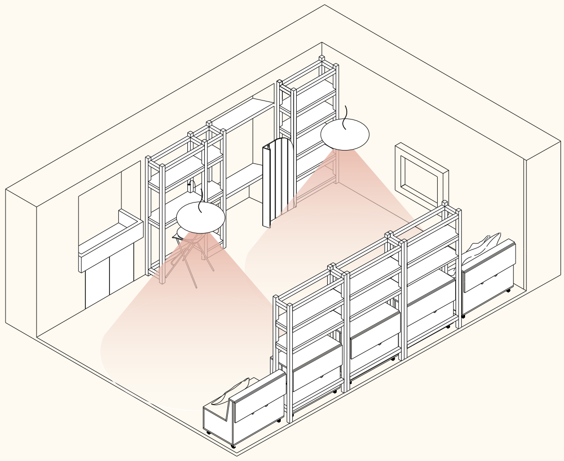
Figure 4.30
Types of lighting

GENERAL

BuzziDome

Noise-reducing ceiling suspended light in-stalled on the vault

#2



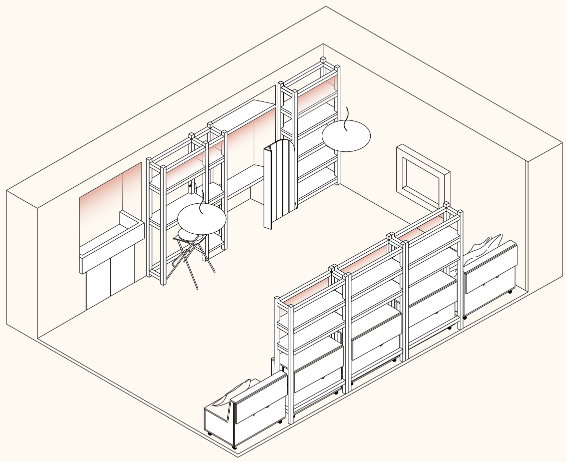
ACCENT

RIGA indoor

Flexible LED strip placed:

- on the libraries' top "beam"
- on the ceiling above the sink
- under the shelf of the niche

#7

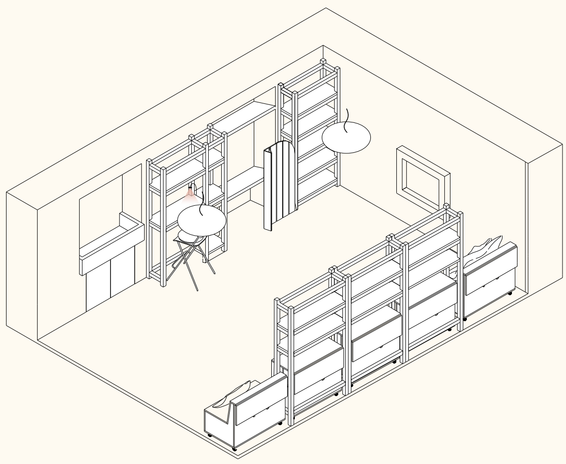


TASK

Nävlinge

Desk light .
One light with clamp for each desk and one for the coffee table

#6



SYSTEMS

Figure 4.31

Lighting fixtures

GENERAL

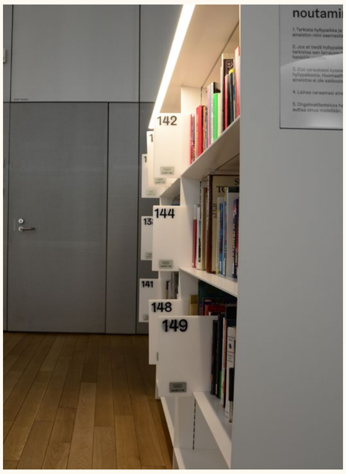
BuzziDome

by Buzzi Space

This fixture was selected for its light efficiency, sound absorption and the variety of colours. It would thus be the best option but, being an high priced product, other options could be evaluated:

1. Under The Bell Pendant Lamp, *by Muuto*
2. Regular lighting fixture + noise absorbing panels

ACCENT



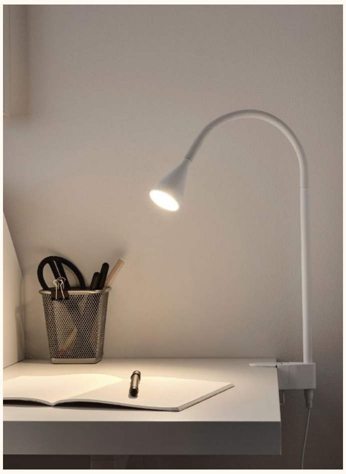
RIGA indoor

by Nemo

RIGA is a product family with a selection of flexible LED strips.

It has been chosen for its small dimension, ease of installation and light source.

TASK

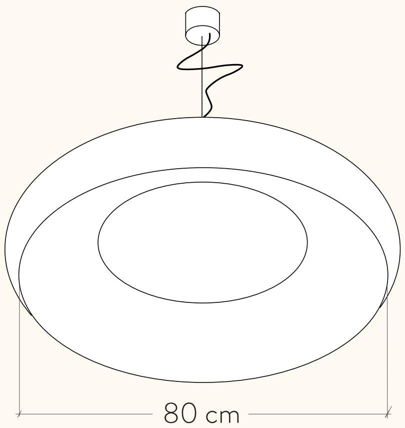


Nävlinge

by Henrik Preutz, IKEA

The lamp can be mounted in two ways: as a clamp spotlight or as a wall lamp. It is lightweight, easy to move and to adjust.

Nävlinge has been picked because of its super-slim design and ease of assembly.



Components

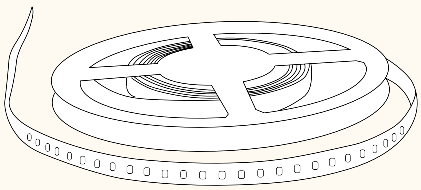
- Upholstered acoustic foam shade
- PMMA opaque diffusor which ensures an optimal light spread and efficiency.
- Powder coated metal ceiling canopy in white (RAL 9010)
- Transparent power cable (4m)

Light source

- Source: 36 low power PCB LED's.
- Total power: 29W
- Luminous flux: 2545 lm
- Colour temperature: 3000K

Energy Class

A++



500x0,8x0,3cm

Components

- White PVC profile
- Opal polyurethane resin.

The installation can be done with double-sided tape already affixed.

Light source

- Source: 12V LED
- Total power: 25W
- Luminous flux: 350lm
- Colour temperature: 3000K

Energy Class

A+

Components

- Optical lens/ Shade: Polycarbonate plastic
- Tube/ Clamp: Steel, Powder coating
- Mounting bracket: Steel, Nickel plated

Light source

- Source: LED
- Total power: 22W
- Luminous flux: 220lm
- Colour temperature: 2700K

Energy Class

A++

MATERIALS

The geographical and social context strongly influenced material selection. Indeed, some materials were locally sourced and others donated. Moreover, some volunteers not only provided materials but also offered their work and knowledge to do the restoration works. Regardless, the major approach that has been taken in the material selection process is reuse. Salvaged solid larch wood, coming from the failure of a construction company will indeed be the main material. Furthermore, also the chestnut wood coming from the previous existing floor will be recovered and reused. However, not all the materials need could be found used thus some, like concrete, plaster and brick, will be bought. As mentioned beforehand, also the way in which materials are assembled contribute to sustainability. To favour this, two systems have been selected (Clamex and Torpedo CSIS) which allow the materials to be easily assembled and disassembled, and the connector to be totally removed from the wood.

Figure 4.32

Material plan, scale 1: 50

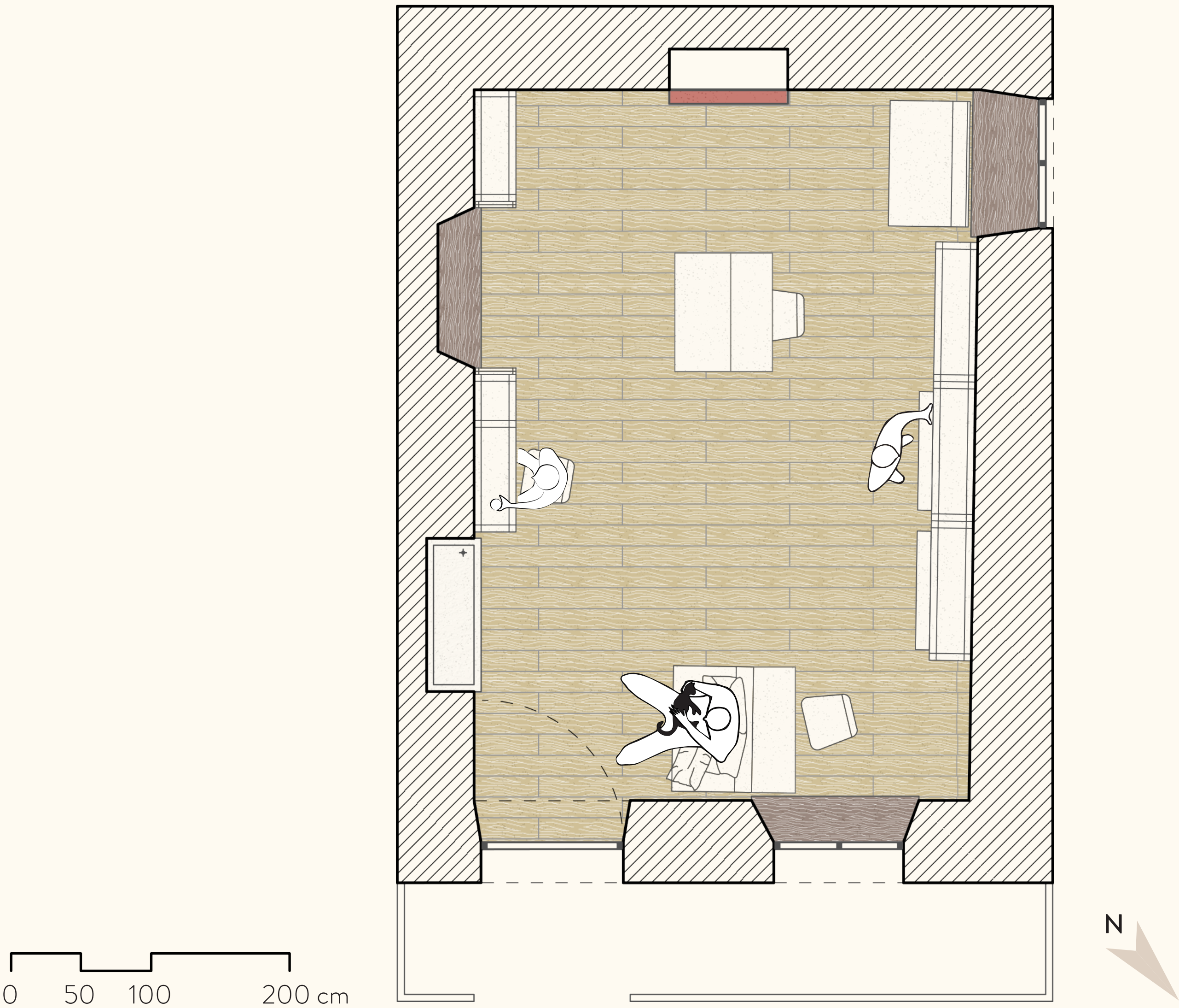


Figure 4.33
Timber used

WHY TIMBER?

- CO_2 storage
- renewable resource
- ease of maintenance
- no harsh chemicals needed
- better acoustic
- better indoor air quality
- feel of warmth
- local resource
- can be refinished rather than replaced
- strength and durability

TYPES OF TIMBER

Chestnut

salvaged + local

from: pavement
to: window sills and shelves

The previously existing pavement was made in local chestnut wood, which is a local wood. A member of the association volunteered to use it to make shelves, window sills and eventually restore the window fixtures.

Larch

salvaged

from: company failure
to: pavement and furniture

Larch is not a local wood but, being a rescued resource, will favour the project sustainability by avoiding the need to cut new forests. Moreover, it will fit well in the context and will give the space the feeling of being in the Alps.

ASSEMBLIES

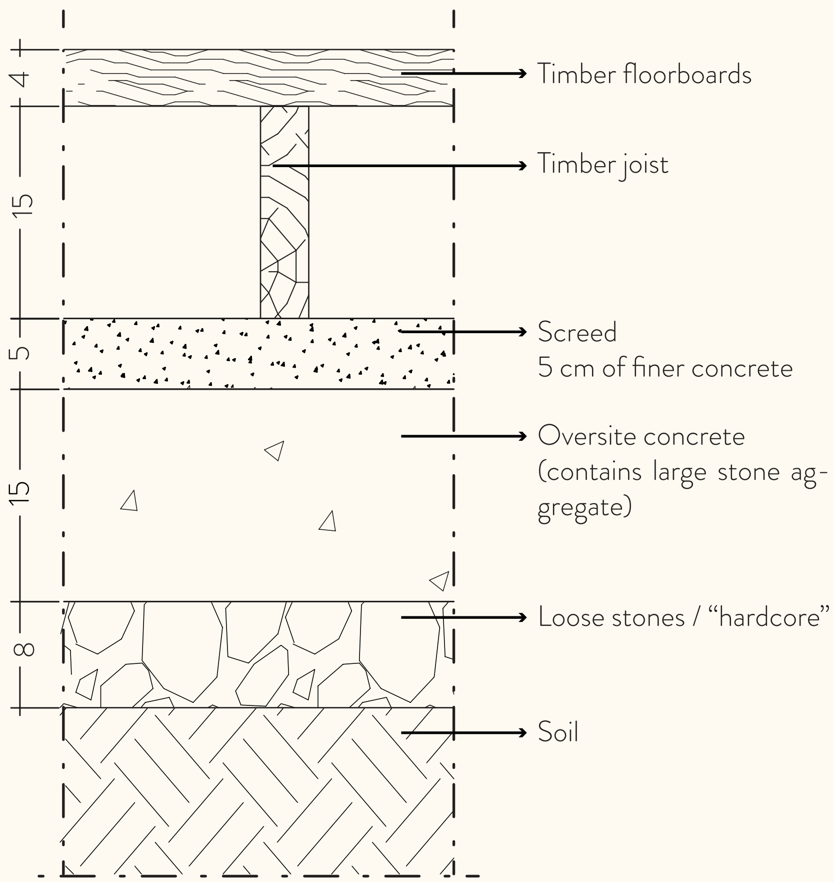
The space' assemblies have been ruined by humidity and poor maintenance, thus it will be necessary to renovate them.

The existing chestnut parquet will be removed and substituted by a larch one. First, the old pavement will be dismantled, then a layer of concrete will be poured to repair the surface. Later a thin layer of cement will be added to flatten the surface and after the new parquet will be installed.
The parquet will be installed as a suspended timber floor, which means that the larch floorboards will be attached to joists just above the cement layer. The small gap in between allows ventilation and air movement and thus prevent damp forming in the timber joists and dissipate moisture, condensation and humidity. This technique is quite old fashioned but avoids using adhesives, which can off-gas VOCs and allows the pavement to be eventually salvaged (Winchip, 2011).

Figure 4.34

Section of the pavement, scale 1: 5

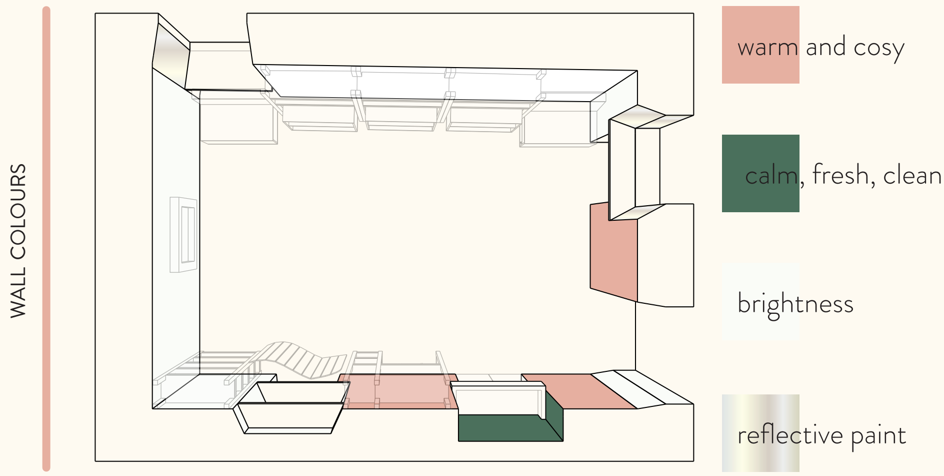
FLOOR DETAIL

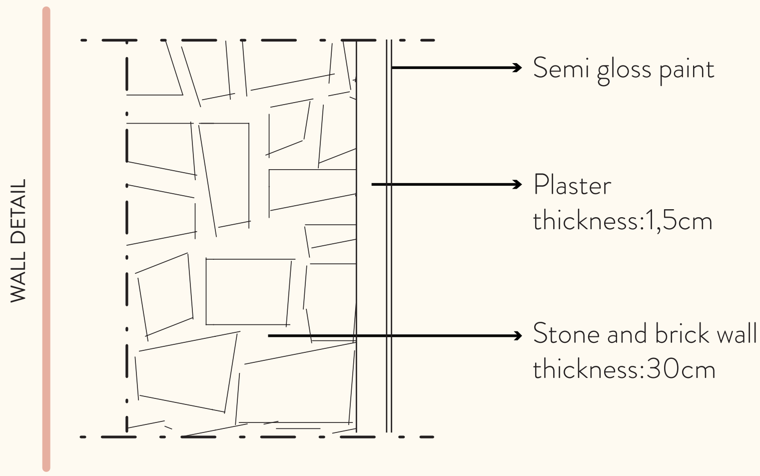


The current plaster will be removed and a new layer will be laid. The texture of the latter will be quite relevant because, with the paint colour, will affect the light reflectance of the surfaces (Binggeli, 2014). The room only has two small apertures thus a smooth texture will be preferred in order to favour the spreading of daylight throughout interior space and improve the efficacy of interior lighting. This will be also be increased by the application of semi-gloss paint on top of the plaster. The main colour used will be white but also a peach beige and a foliage green will be used in some areas. White has been chosen because it visually enlarges the room dimensions and because it maximises the light reflectance of the walls and thus diminishes the need for artificial lighting. This has also been enhanced by applying reflective paint on the side walls of the windows.
Since coatings like paint often emit VOCs, reducing indoor air quality a water-based paint, which usually emit fewer VOCs (Godsey, 2017) will be chosen.

Figure 4.35

Wall colours and section of the wall, scale 1: 5

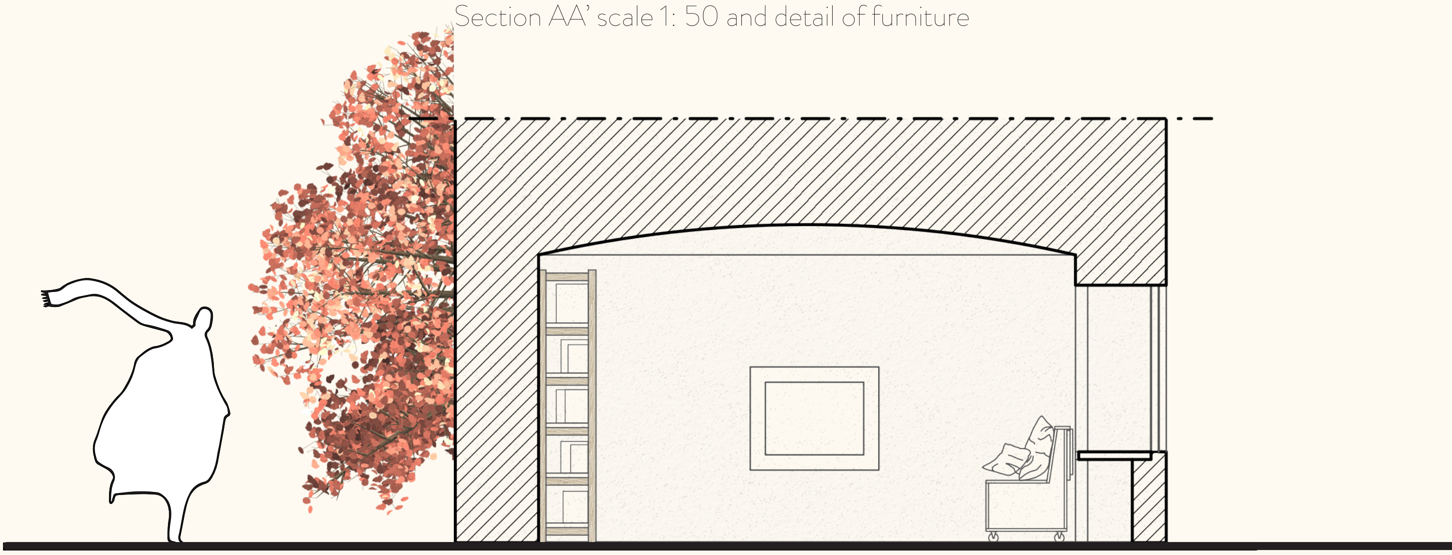




FURNITURE

Figure 4.36

Section AA' scale 1: 50 and detail of furniture



BOOKCASE

MATERIALS: larch wood, white wood paint

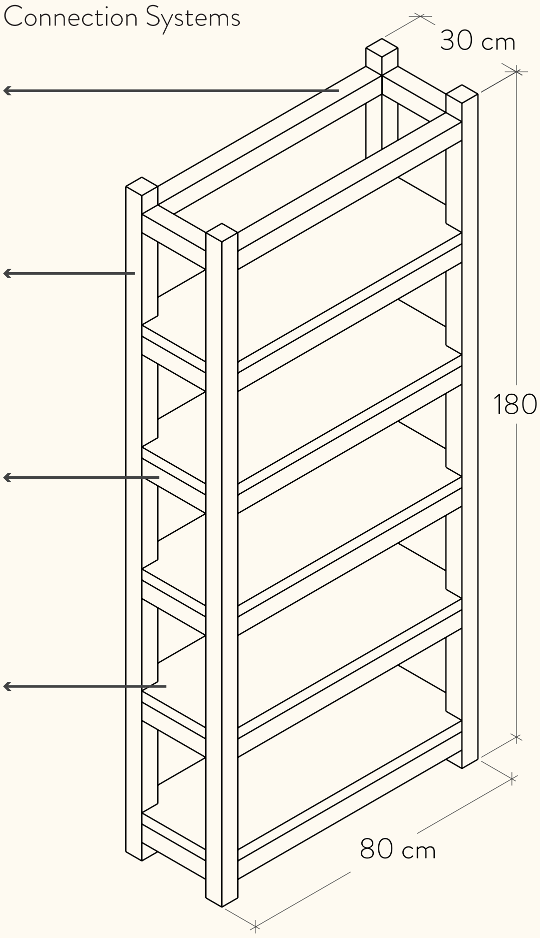
HARDWARE: TorpedoCSIS Connection Systems

CROSS BEAMS
- larch wood
- section: 5x5cm
- length: 80cm

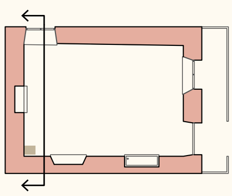
STUDS
- larch wood
- section: 5x5cm
- length: 180cm

CROSS BEAMS
- larch wood
- section: 5x5cm
- length: 20cm

SHELF
- white painted larch wood
- thickness: 3cm
- dimensions: 80x30cm



AA'

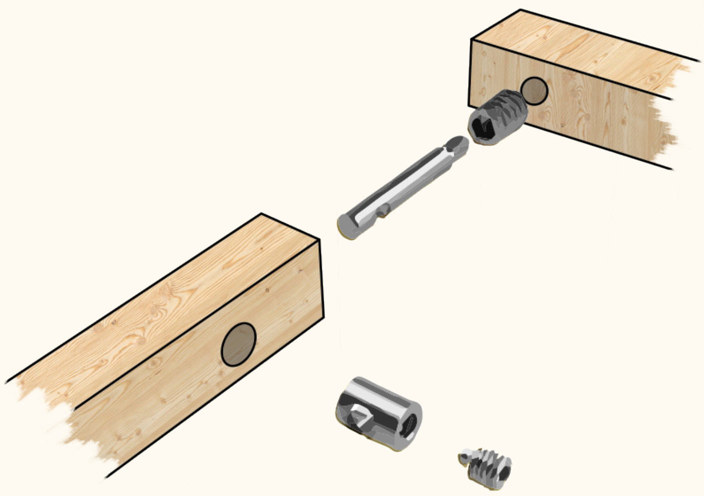


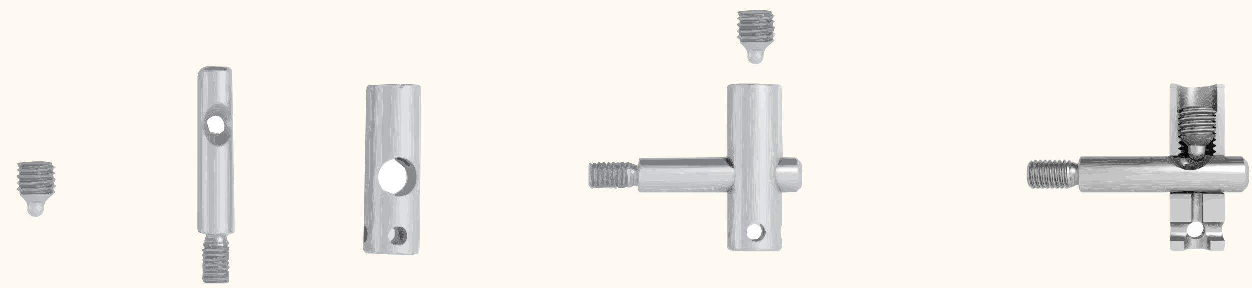
0 50 100 200 cm

TORPEDO CSIS CONNECTION SYSTEMS

Torpedo CSIS is a single step shafting and clamping system that:

- Accelerate assembly
- Make it possible to assemble and take apart, without compromising strength or quality of joints
- Is compatible with standard tools, eliminating the need for additional set-up fees
- Minimizes costs traditionally associated with manufacturing
- Simplifies production by decreasing the number of steps involved with assembly

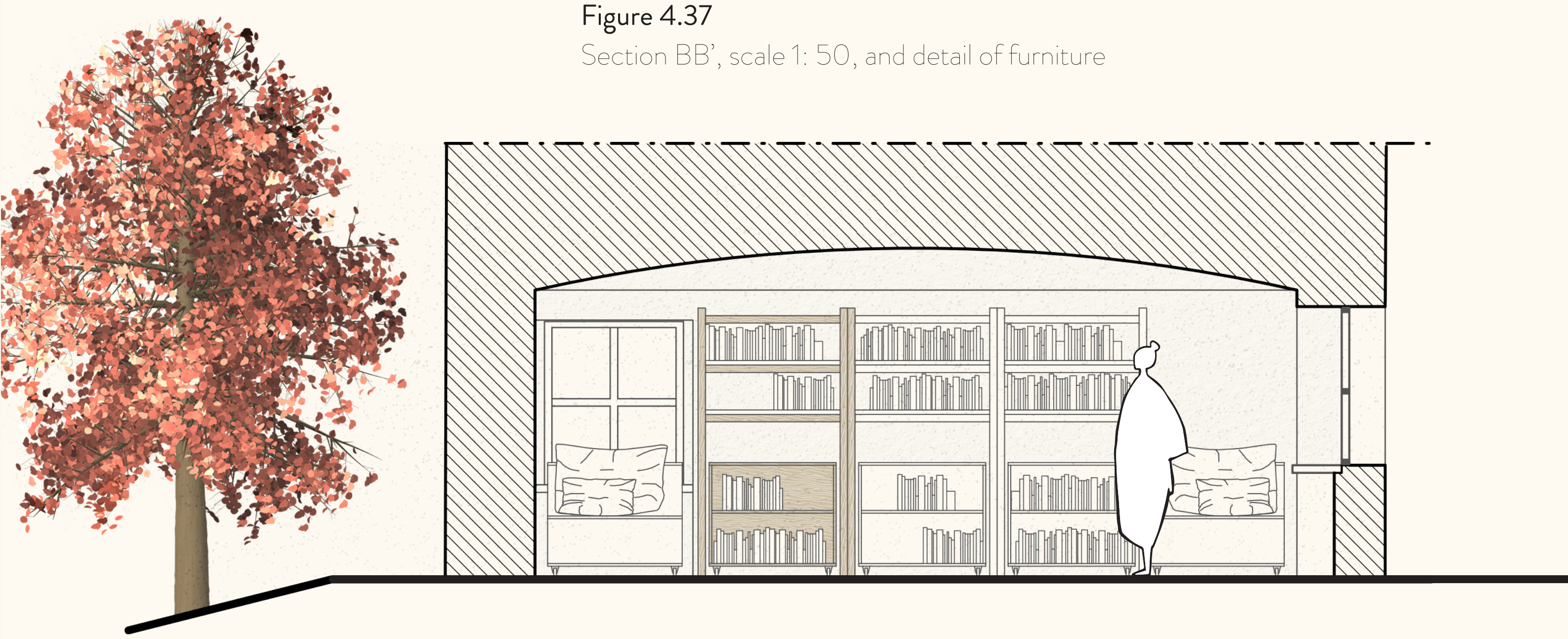




grub screw   shaft bolt   housing

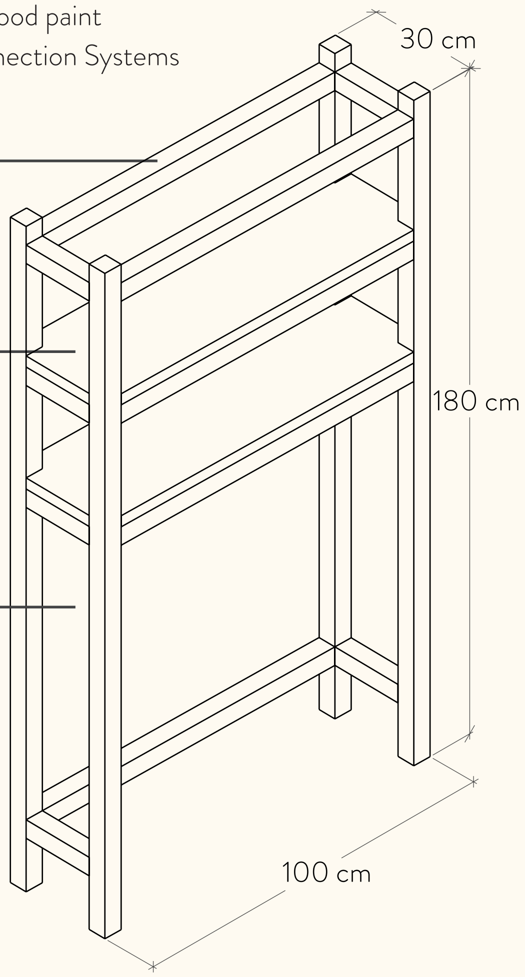
Figure 4.37

Section BB', scale 1: 50, and detail of furniture



BOOKCASE

MATERIALS: larch wood, white wood paint
HARDWARE: TorpedoCSIS Connection Systems



CROSS BEAMS

- larch wood
- section: 5x5cm
- length: 80cm

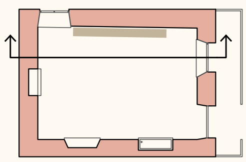
SHELF

- white painted larch wood
- thickness: 3cm
- dimensions: 90x30cm

VOID

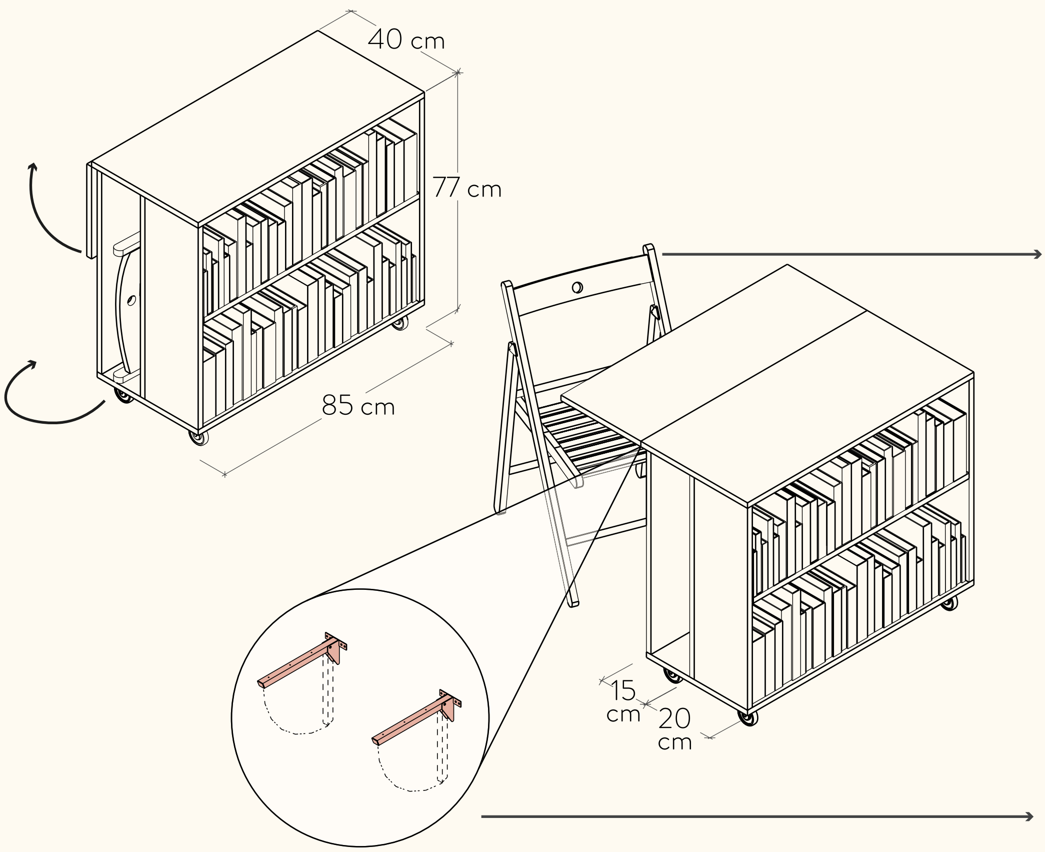
- volume (90x90x25 cm) left to host the rolling bookcase with desk

BB'



ROLLING BOOKCASE WITH FOLDING DESK

MATERIAL: larch wood (1,8 cm)
HARDWARE: Lamello Clamex; stainless steel folding brackets; wheels.



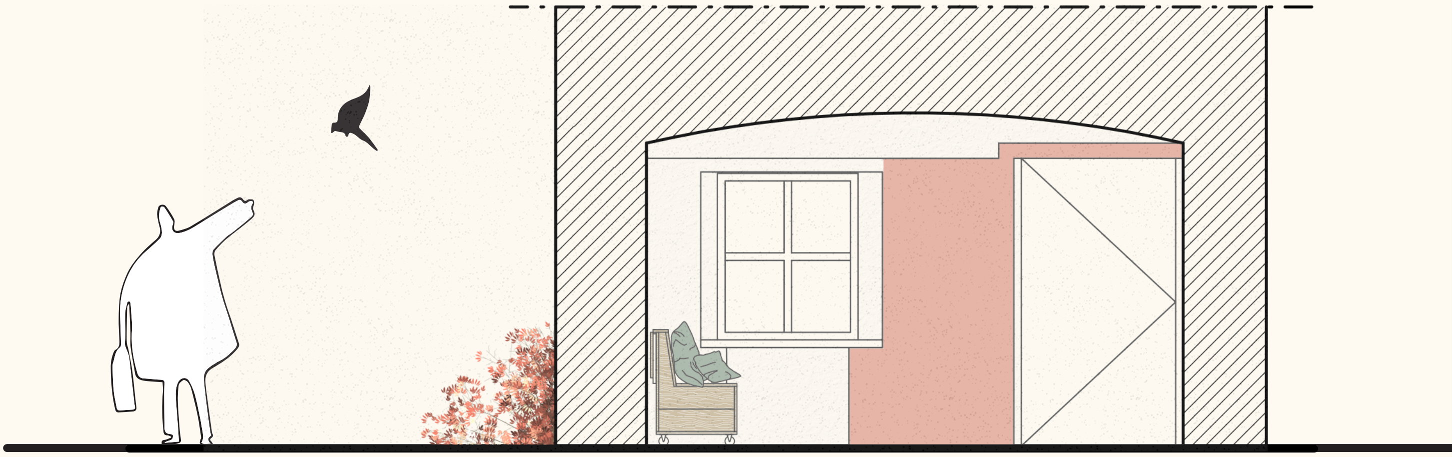
FOLDING CHAIR

- Ikea Terje, white, beech wood.

FOLDING BRACKETS

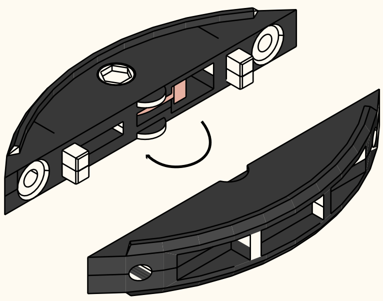
- self locking stainless steel folding brack-ets

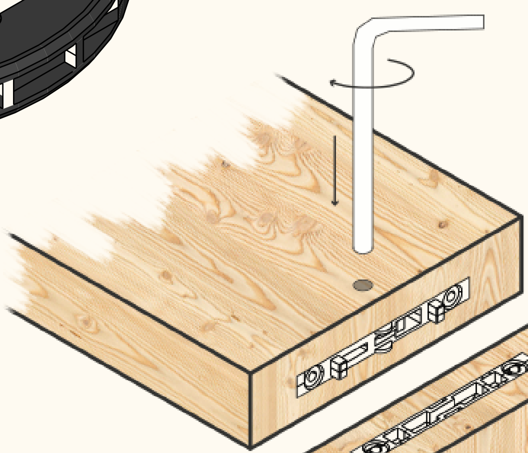
Figure 4.38
Section CC', scale 1: 50, and detail of furniture

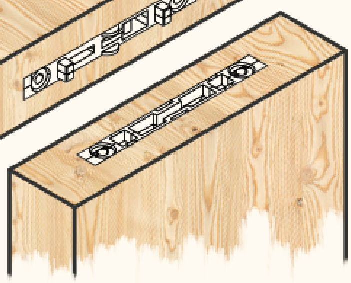


LAMELLO CLAMEX

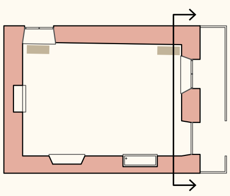
Clamex is a detachable connecting system developed by Lamello that is screwed into an 8 mm groove and connected via a lever. Workpieces connected with Clamex can be detached at any time using a simple rotating lever. To open and close the connector only a small, barely visible tool opening of 6mm is used.





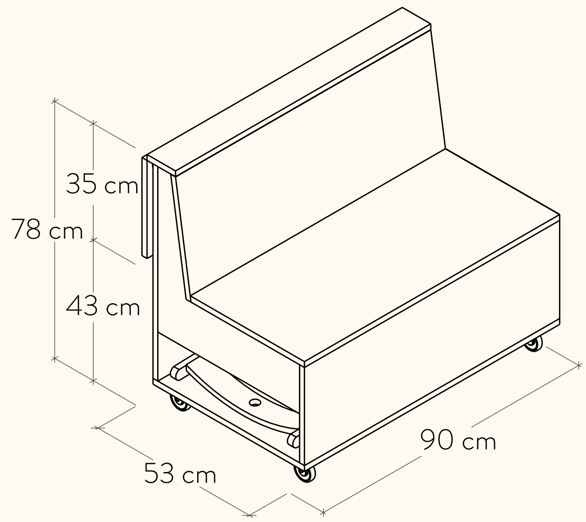


CC'



ROLLING COUCH WITH FOLDING DESK

MATERIAL: larch wood (1,8 cm)
HARDWARE: Lamello Clamex; steel folding brackets; wheels.



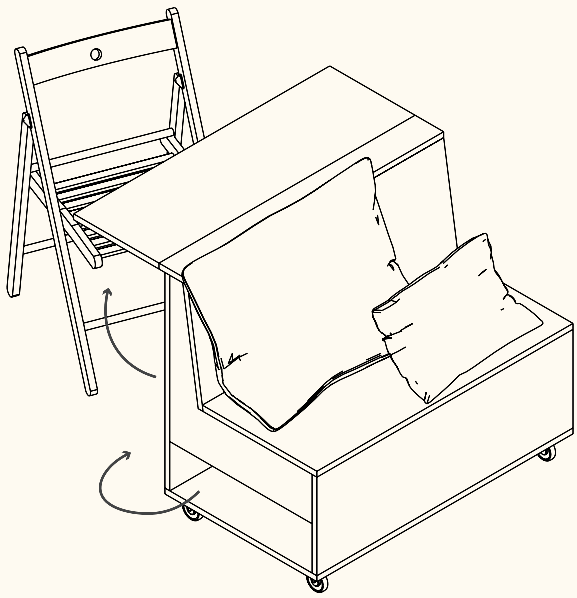
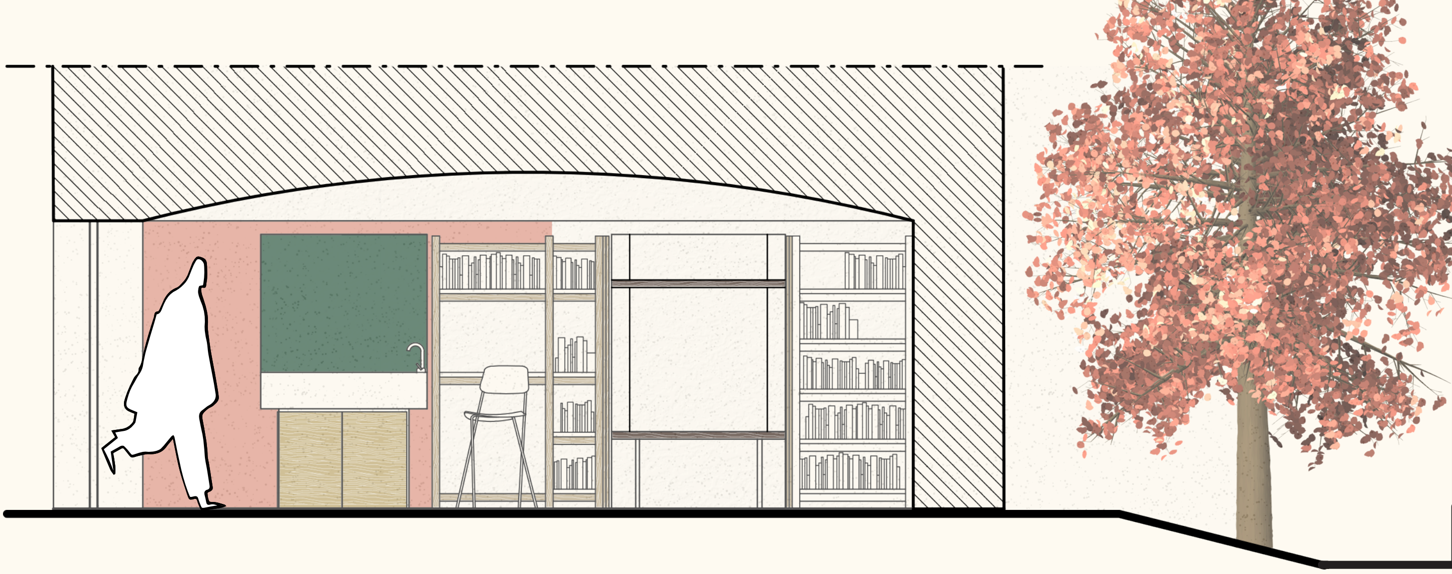


Figure 4.39

Section DD’, scale 1: 50, and detail of furniture



CABINET

MATERIALS: larch wood, white wood paint

HARDWARE: steel hinges, screws

The sink will be furnished with a shelf that will serve as a counter top.

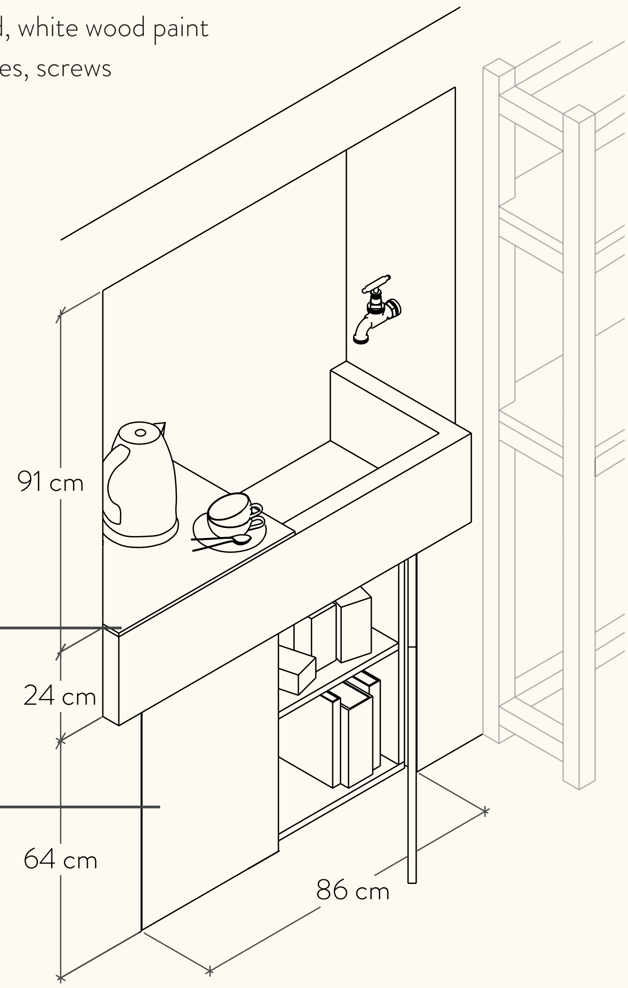
The underneath cabinet will store the library’ register and other documents.

SINK SHELF

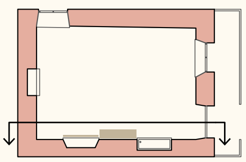
- larch wood
- thickness: 1,8cm

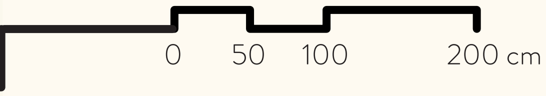
CABINET

- white painted larch wood
- thickness: 1,8cm



DD’





BOOKSHELF AND BREAK AREA

MATERIALS: larch wood, white wood paint
HARDWARE: TorpedoCSIS Connection Systems

This bookshelf and desk piece will serve both as a coffee table, where users could take a break while enjoying a cup of tea or coffee and as the registry desk. Here, the volunteer in charge of running the place can register the loans and returns

The shelf above will be used to collect the returned books that will be later reorganised by the volunteer.

SHELF FOR RETURNED BOOKS

DESK
- white painted larch wood
- thickness: 3cm
- dimensions: 80x30cm

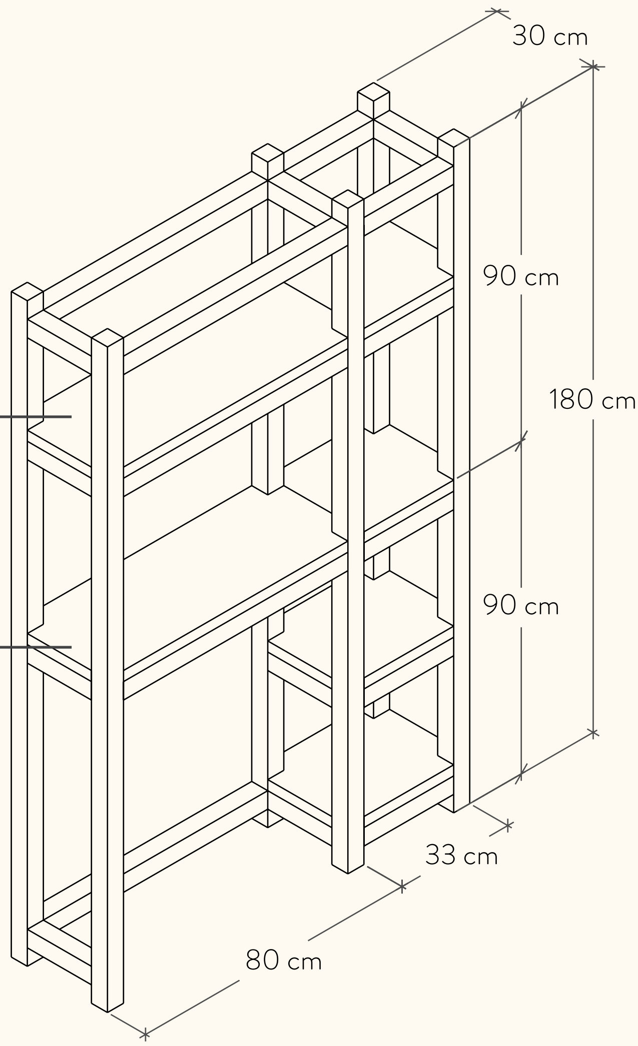
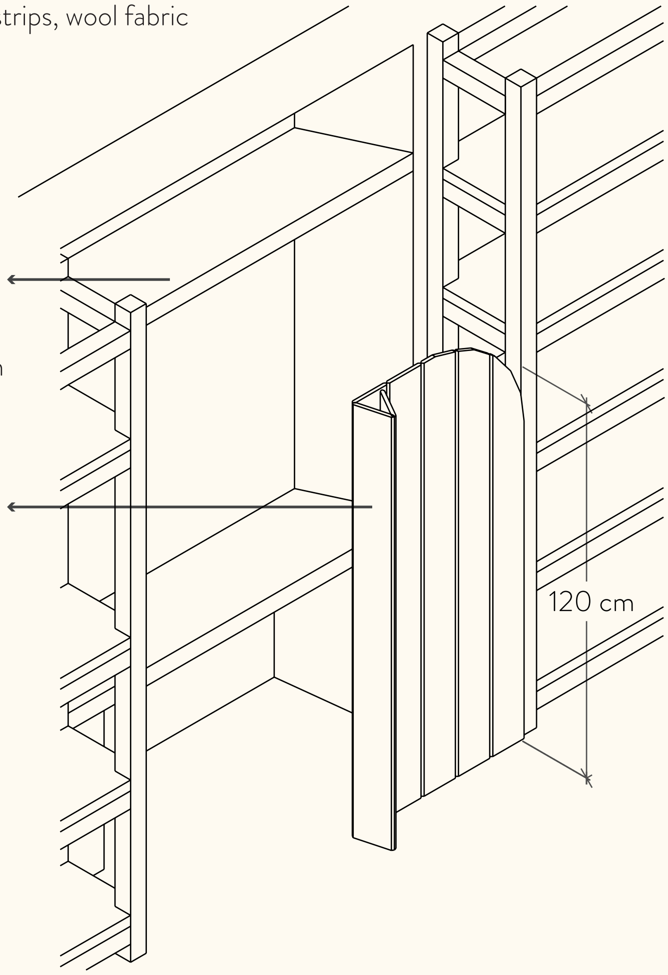


Figure 4.40
Call booth

CALL BOOTH

MATERIALS: MDF strips, wool fabric



STORAGE SHELF

- chestnut wood
- thickness: 4cm

FOCUS

- MDF strips
- wool fabric
- length: 120cm
- height: 120cm

To create the call booth, Zilenzio floor screen, Focus, will be used. Focus is a lightweight and foldable screen designed by Note Design Studio made of fabric for the surface and MDF strips of width 2.5 mm for the support. What allows Focus to be folded are the seams, which avoid the need for metal hardware.

This product has been chosen to bring softness, cosiness and colours to the space.

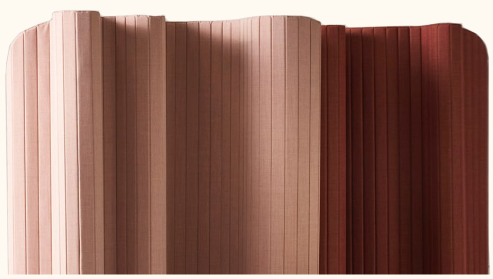
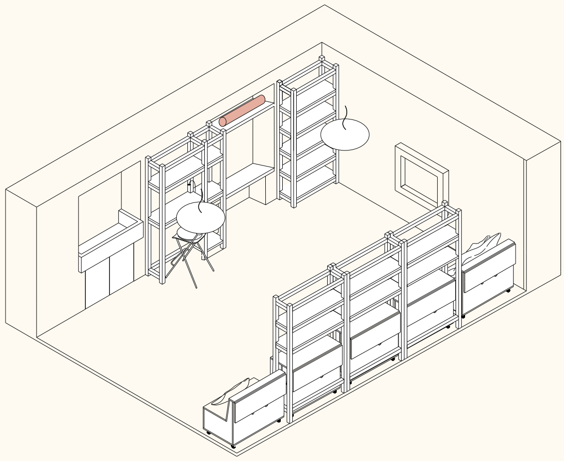


Figure 4.41

Types of lighting

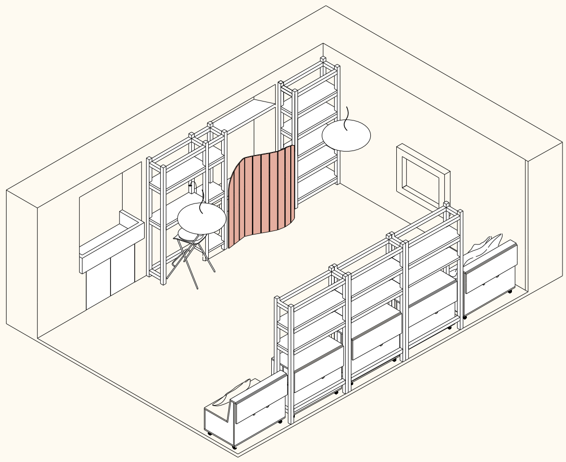
1

When not needed, Focus partitions could be rolled up and stored on the shelf in the niche. There, also a small laptop stand could be stored.



2

When needed, they can be easily taken out and unrolled in front of the niche, to separate it from the room and giving more privacy to those users needing to make video calls. This, transforms the niche in a call booth.



3

The elements could also be moved and used around the library to provide more privacy to the users, better acoustic. Moreover, the elements will give character to the space with their colours, soft materials and curved shapes.

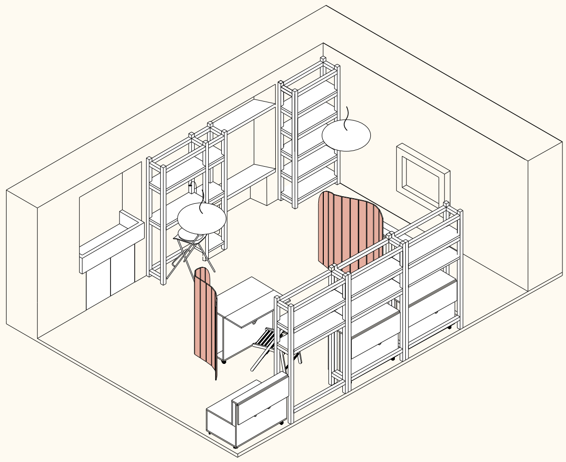
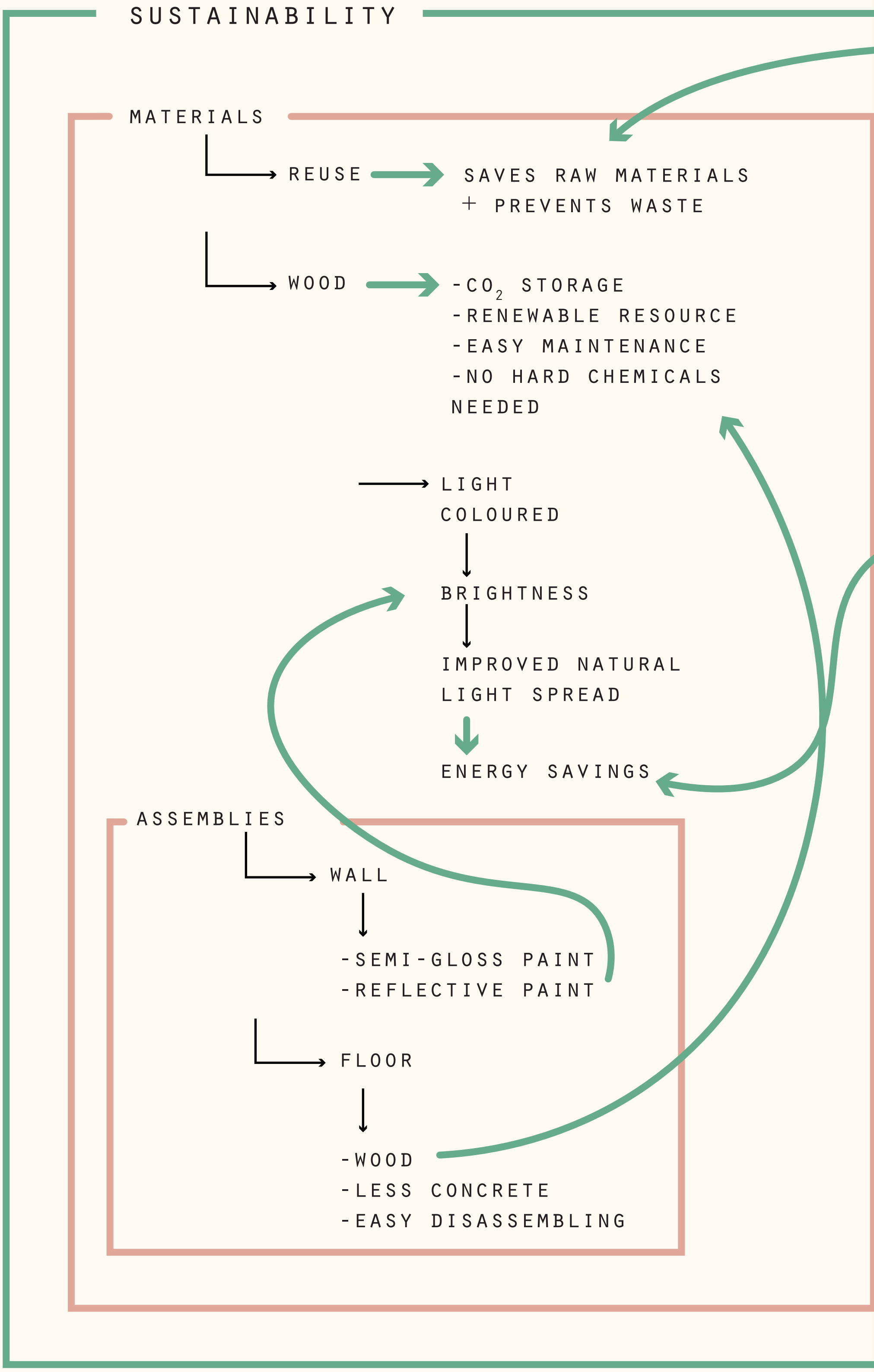


Figure 4.41
Summary of the environmentally sustainable strategies applied



SYSTEMS

→ HEATING

↓

FIRE PLACE BURING
LOCALLY SOURCED
WOOD

→ LIGHTING

↓

-LED FIXTURES
-SEPARATED SWITCHS

STRATEGIES

→ MULTIFUNTIONALITY

↓

LESS MATERIALS NEEDED

→ FLEXIBILITY

↓

MORE FUNCTIONS
POSSIBLE IN LESS SPACE

→ MODULARITY

↓

EASIER BUILDING AND
REUSE

→ DISASSEBLY

↓

EASY AND RESPONSIBLE
DISMANTLING

→ SHARING

↓

LESS PER CAPITA
CONSUMPTION

Figure 4.42
Photo collage, 1

Figure 4.43
Photo collage, view 2

Figure 4.44
Photo collage, view 3

Figure 4.45
Photo collage, view 4

Figure 4.46

Photo collage, view from the fireplace

Figure 4.47
Photo collage, view from the entrance


GAUDI
CASE STUDY HOUSES
JAPANESE PRINTS
Scandinavian
New York
BREUER

5 Conclusions

5.1 Conclusions

Global population is growing, consumption increasing, and resource depletion escalating. Everything at the expenses of the environment in which we live, and that enabled the development of humanity and still sustains us today. Human activity, with its large emissions of greenhouse gases and irresponsible management of resources, is damaging the Earth ecosystems provoking unprecedented environmental changes. Temperatures are rising, glaciers and sea ice are melting at a faster rate, sea levels are rising, droughts are becoming longer and more extreme, biodiversity is getting lost and so on. This path is threatening our generation and future ones.

Luckily, there are actions we can take to tackle this problem for our own sake and the benefit of other species. Many measures can be taken across different sectors including the energy supply, and the materials management sector. The latter is what this dissertation focused on.
Materials are resources that have enabled the advance of humanity from its earliest beginnings, played a crucial role in advancing technology, and are the heart of maintaining high standards of living and a healthy industrial sector. However, our current use of them follows a linear path characterised by the sequence "take-make-use-dispose" which the planet can't afford. The concept of the "circular economy" offers the opportunity of shifting away from this linear model and embrace a more circular one, where materials are not seen as a disposable commodity, but rather as a valuable asset to be tracked, conserved.

The construction industry, which, with its substantial use of materials, generates consistent impacts on the environment, can play a crucial role in this transition to a circular economy. Interior designers, as figures operating in this sector, should play an active part in favouring a more responsible use of materials and mitigating the environmental consequences of their work.

Nonetheless, sustainability is not always easy and straightforward to frame and therefore introducing it into the practice of design is not a simple task. The definition of what is sustainable can vary widely depending on several factors hence it is impossible to find a one size fits all material, assembly, or solution. In this dissertation have been explored strategies and approaches that can favour the environmental sustainability of a project.
Much importance has been given to materials and how designers can select and use them to favour environmentally sustainable interiors. Interiors, having much shorter lifetimes than buildings, get renovated more often, and thus consume resources and produce great amount of waste. To avoid this, the major considerations that professionals can make involves the interior lifetime and life cycle, and the selection and assembly of materials.

Considering an interior lifetime and life cycle empowers designers to choose materials and building techniques that are suited to this period and allow them to plan accordingly for demolition, flexibility, or future adaptability (Moxon, 2012), hence preventing waste and unnecessary need for new resources. Also carefully selecting materials can favour this. In the material selection process, the main strategies that can be applied to carry out a more environmentally sustainable material selection can be summarized in the three R's rule: reduce, reuse, recycle, to which it would be right to add using renewables when it comes to specifying building materials. Reduce the need for materials, reuse the ones already in use, recycle the ones that cannot be reused and ensure that any new material used is renewable (Moxon, 2012).
Other tactics that designers can also employ to favour environmentally sustainable interiors include designing for flexibility, multifunctionality, disassembly, modularity and sharing. Moreover, designers can make a valuable difference, not only through their design role on projects but also thanks to their capacity to influence and support the wider design team (Moxon, 2012).

Environmentally sustainable design is thus more an approach than a prescribed aesthetic style. It involves taking care of the environment in which the project is located, being aware of the impacts of our choices, looking at the future of the project and many other concerns. Developing a project is, in fact, a complex business that requires taking tough decisions. In this work, it has thus been attempted to delineate some simple guidelines to achieve more environmentally sustainable interiors. The steps outlined have a focus on materials and, therefore, they are not comprehensive of all the possible sustainable measures. More complete and in-depth guidelines, including considerations regarding systems, technologies and users behaviours could be drawn and be collected in a guidebook for young designers.

The steps previously mentioned have been followed to develop R library, the project for a small library and coworking, presented in the final section of this work. The project has been shaped around the concept of adaptability and metamorphosis and designed with one leading principle: sustainability. Great attention has been placed on the material selection, their use and assembly. R library is thus an exercise, an experiment in which environmental sustainability was given the highest priority and all the possible sustainable strategies applicable have been employed.

Environmental issues cannot be ignored any longer. Sustainability must be an integral part of every project and only an environmentally sustainable design solution could be considered successful. Nonetheless, this should be seen as a challenge rather than a chore. After all, design is problem-solving and environmental damage is "simply" another problem that designers must help to solve (Moxon, 2012).

References

Abbeceddario minimo(2017). In Chiara Dezzi Bardeschi (Ed.). Firenze: Altralinea Edizioni.

ALA Architects. (2020). Oodi helsinki central library / ALA architects. Retrieved 06/10, 2020, from https://www.archdaily.com/907675/oodi-helsinki-central-library-ala-architects

Allen, E., & Iano, J. (2014). *Fundamentals of building construction: Materials and methods*. (6th ed.). Hoboken: Wiley.

Allwood J., C. J. (2012). *Sustainable materials: With both eyes open*. Cambridge.

AMIPLAS. (2016). *Plastic materials in construction: Latest business statistics of the sector*. Retrieved 04/15, 2020, from https://www.aimplas.net/blog/plastic-materials-in-construction-latest-business-statistics-of-the-sector/

Ashby, M. F. (2012). *Materials and the environment : Eco-informed material choice*.

Ashby, M. F., Ferrer B. D., & Segalas C. J. (2016). *Materials and sustainable development*. Oxford: Butterworth-Heinemann.

Ashby, M. F., & Johnson, K. (2002). *Materials and design: The art and science of material selection in product design*. (3rd ed.). Oxford: Butterworth-Heinemann.

Bhatta, S., Tiippana, K., Vahtikari, K., Kiviluoma, P., Hughes, M., & Kyttä, M. (2019). *Quantifying the sensation of temperature: A new method for evaluating the thermal behaviour of building materials*. Energy and Buildings, 195, 26-32.

Binggeli, C. (2014). *Materials for interior environments*. (2nd ed ed.). Hoboken, New Jersey: John Wiley & Sons.

Binggeli, C. (2016). *Building systems for interior designers*. John Wiley & Sons, Incorporated.

Block, I. (2020). *Nordest arquitectura uses wooden partitions to convert old barn into offices for its studio*. Retrieved 06/10, 2020, from https://www.dezeen.com/2020/06/16/nordest-arquitectura-architects-studio-offices-barn-conversion-spain/

Boniwell, I. (2008). *What is eudaimonia? the concept of eudaimonic well-being and happiness.* Retrieved 11/10, 2019, from http://positivepsychology.org.uk/the-concept-of-eudaimonic-well-being/

British Petroleum. *Energy demand by sector*. Retrieved 02/06, 2020, from https://www.bp.com/en/global/corporate/energy-economics/energy-outlook/demand-by-sector.html

Broadgate, W., Deutsch, L., Gaffney, O., Ludwig, C., & Steffen, W. (2015). *The trajectory of the anthropocene: The great acceleration*. The Anthropocene Review.

Brostow, W. (2017). *Materials: Introduction and applications.* Hoboken, New Jersey: Wiley.

Brown, R., & Farrelly, L. (2012). *Materials and interior design.* London: Laurence King.

C2C Certified. (2017). *What is design for disassembly?*. Retrieved 07/07, 2020, from https://www.c2ccertified.org/news/article/what-is-design-for-disassembly

Cambridge Dictionary. (n.d.). *Carbon cycle.* Retrieved 17/05, 2020, from https://dictionary.cambridge.org/dictionary/english/carbon-cycle

Cambridge Dictionary. (n.d.). *Material*. Retrieved 26/01, 2020, from https://dictionary.cambridge.org/it/dizionario/inglese/material

Candido, R., Godoy, G. & Gonçalves, A. R. (2017). Characterization and application of cellulose acetate synthesized from sugarcane bagasse. Carbohydrate Polymers, 167, pp. 280-289. doi:10.1016/j.carbpol.2017.03.057

Carlson, C. (2020). University of stuttgart builds prototype thatched alpine hut. Retrieved 10/10, 2020, from https://www.dezeen.com/2020/09/26/university-stuttgart-thatched-alpine-hut-skinover-reed/#/

Council for Interior Design Qualification. (2019). *Interior design*. Retrieved 02/12, 2020, from https://www.cidq.org/definition-of-interior-design

Crook, L. (2019). *Studio bark's flat-pack U-build system lets anyone self-build*. Retrieved 06/15, 2020, from https://www.dezeen.com/2019/05/10/ubuild-studio-bark-modular-architecture/

Crouch, M., Friggens, S., & Wildfire, C. (2019). In Mott Mac Donald (Ed.), Zero: Building a net-zero economy

Davis, A. (2014). *Scaffolding forms temporary clothing rails at berlin pop-up shop by kontent*. Retrieved 07/08, 2020, from https://www.dezeen.com/2014/06/08/concept-store-in-berlin-by-kontent/

de Wit, M., Hoogzaad, J., & von Daniels, C. (2019). *The circularity gap report* 2019. Amsterdam.

Del Curto, B., Marano, C., & Pedeferri, M. P. (2015). *Materiali per il design. introduzione ai materiali e alle loro proprietà*. Milano: Ambrosiana.

Ellen Mac Arthur Foundation. *Circular economy, concept.* Retrieved 30/01, 2020, from https://www.ellenmacarthurfoundation.org/circular-economy/concept

Encyclopaedia Britannica. (2009). *Cellulose acetate*. Retrieved 04/19, 2020, from https://www.britannica.com/science/cellulose-acetate

European Commission, E. (2020). Paris agreement. Retrieved 10/19, 2020, from https://ec.europa.eu/clima/policies/international/negotiations/paris_en

European Commission, E. (2019). *Waste streams: Construction and demolition waste*. Retrieved 02/24, 2020, from https://ec.europa.eu/environment/waste/construction_demolition.htm

European Parliament. (2018). Circular economy: Definition, importance and benefits. Retrieved 09/23, 2020, from https://www.europarl.europa.eu/news/en/headlines/economy/20151201STO05603/circular-economy-definition-importance-and-benefits

Ezema, I. C. (2019). In Tam V. W. Y., Le K. N.(Eds.), Chapter 9 - materials Butterworth-Heinemann. doi:https://doi.org/10.1016/B978-0-12-811749-1.00007-9

Fairis, M. (2020). *Note design studio's re-usable stand for vestre explains the carbon emissions of each product*. Retrieved 07/01, 2020, from https://www.dezeen.com/2020/02/07/vestre-note-design-studio-stockholm-furniture-light-fair-best-stand/

Frearson, A. (2020). Studio inches adds concrete and granite gallery to alpine art museum. Retrieved 10/10, 2020, from https://www.dezeen.com/2016/06/15/museo-mecri-studio-inches-concrete-granite-gallery-minusio-switzerland/

Geren, R. L. (2010). *Difference between building materials, finishes and color*. Retrieved 03/20, 2020, from http://discus.4specs.com/discus/messages/7463/5333.html?1292422009

Gibson, E. (2016). *Studio ben allen inserts pale plywood children's bedroom into barbican flat*. Retrieved 06/10, 2020, from https://www.dezeen-com/2017/10/08/a-room-for-studio-ben-allen-london-barbican-estate-flat/

Global Alliance for Buildings and Construction, International Energy Agency, United Nations Environment Programme. (2019). *2019 global status report for buildings and construction*

Godsey, L. (2017). *Interior design materials and specifications* (3rd ed.). New York, NY: Fairchild Books, an imprint of Bloomsbury Publishing Inc.

Granta Design Limited. (2020). CES EduPack software. Cambridge:

Green, J. P. (2014). *Sustainable plastics : Environmental assessments of biobased, biodegradable, and recycled plastics*. Hoboken, New Jersey: John Wiley & Sons, Inc.

GRIP metal. Retrieved 07/08, 2020, from https://www.gripmetal.com/

Hahn, N. (2020). Sabine marcelis designs work-from-home cubicle with bright yellow interior. Retrieved 10/30, 2020, from https://www.dezeen.com/2020/01/09/flat-house-hempcrete-practice-architecture-margent-farm/?li_source=LI&li_medium=rhs_block_3

Hanemaaijer, A., Hekkert, M., Potting, J., & and Worrell, E. (2017). *Circular economy: Measuring innovation in the product chain.* PBL Publishers.

Hausen, J. E. (2018). *Minimalist life orientations as a dialogical tool for happiness*. British Journal of Guidance & Counseling.

Info - architecture. (2020). Retrieved 06/10, 2020, from https://www.kansalliskirjasto.fi/en

Interface. (2018). Reentry: Reuse, repurpose, recycle. Retrieved 05/20, 2020, from https://www.interface.com/EU/en-GB/campaign/reentry/reentry-en_GB

International Energy Agency. (2019). Data and statisitcs. Retrieved 01/20, 2020, from https://www.iea.org/data-and-statistics?country=WORLD&fuel=CO2%20emissions&indicator=CO2%20emissions%20by%20sector

Introduction: Interior design. Retrieved 06/03, 2020, from https://www.interiordesign.polimi.it/bachelor-degree-in-interior-design-2/?lang=en

IUAV. (2020). ArTec. Retrieved 09/29, 2020, from http://materioteca.iuav.it/

Jones, L. (2008). *Environmentally responsible design: Green and sustainable design for interior designers*. Hoboken, New Jersey: John Wiley & Sons.

Kataja, K., & Kääriäinen, P. (2018). Desiging cellulose for the future. Helsinki

Kivistö, M. (2020). Helsinki's most stunning libraries. Retrieved 06/10, 2020, from https://www.myhelsinki.fi/en/see-and-do/sights/helsinki%E2%80%99s-most-stunning-libraries

Koca, G. (2016). *Interior finishing materials*. Developments in science and engineering (pp. 588-601) St. Kliment Ohridski University Press.

Lendager group. (2020). Retrieved 05/17, 2020, from https://lendager.com/en/

Madaster. Retrieved 02/11, 2020, from https://www.madaster.com/en

Material district. (2020). Retrieved 29/09, 2020, from https://materialdistrict.com/

Mogu.bio. (2020). Retrieved 09/25, 2020, from https://mogu.bio/about/

Morby, A. (2016). *Rotating walls offer alternative layouts for MJE house by PKMN architectures*. Retrieved 06/25, 2020, from MJE House

Morelli, J. (2011). *Environmental sustainability: A definition for environmental professionals.* Journal of Environmental Sustainability, 1(1)

Moxon, S. (2012). *Sustainability: In interior design*. London: Laurence King.

Navi Finnish Architecture. (2020). Rikhardinkatu library. Retrieved 06/10, 2020, from https://navi.finnisharchitecture.fi/rikhardinkatu-library/

Nordest Arquitectura. (2020). Studio 1700 / nordest arquitectura. Retrieved 06/10, 2020, from https://www.archdaily.com/941123/studio-1700-nordest-arquitectura

Olson, T. P. (2010). *Design for deconstruction and modularity in a sustainable built environment*

Organisation for Economic Co-operation and Development. (2018). *OECD HIGHLIGHTS global material resources outlook to 2060 – economic drivers and environmental consequence*. Paris: OECD Publishing.

Petričević, M. (2007). *Environmentally sustainable interior design-the challenges and trends.*

Petrovic, E., Vale, B., & Zari, M. (2017). Materials for a healthy, ecological and sustainable built environment (1st ed.) Woodhead Publishing.

Phuong, V. T., Verstiche, S., Cinelli, P., Anguillesi, I., Coltelli, M. & Lazzeri, A. (2014). Cellulose Acetate Blends - Effect of Plasticizers on Proper ties and Biodegradability. Journal of Renewable Materials, 2(1), pp. 35-41. doi:10.7569/JRM.2013.634136

Piccinno, G. (2015), Interior design. Ananke, 75, 25.

Pilatowicz, G. (1995). *Eco-interiors: A guide to environmentally conscious interior design*. New York: John Wiley & Sons. Plunkett, D. (2015). *Construction and detailing for interior design* (2nd ed.) Laurence King.

Population Matters. The issue. Retrieved 02/02, 2020, from https://populationmatters.org/

Portney, K. E. (2015). *Sustainability.* MIT Press.

Pownall, A. (2020). *Panter & tourron creates ultra-light and tool-free furniture for global nomads*. Retrieved 10/24, 2020, from https://www.dezeen.com/2019/04/16/panter-tourron-tense-flat-packed-furniture/

QUARTZ. (2019). Quartz common poducts database. Retrieved 05/22, 2020, from https://quartzproject.org/q

Quddus, S. (2020). PKMN architectures creates sliding transformer house in madrid. Retrieved 10/24, 2020, from https://www.archdaily.com/566605/pkmn-architectures-builds-transformer-house-studio-in-madrid

Ravenscroft, T. (2018). *Leopold banchini sinks rooms and objects beneath office floors in centre pompidou installation*. Retrieved 04/05, 2020, from https://www.dezeen.com/2018/08/12/leopold-banchini-3-8-centre-pompidou-installation-design/

Ravenscroft, T. (2020). Running brand on creates zero-impact mountain hut in swiss alps. Retrieved 10/10, 2020, from https://www.dezeen.com/2019/07/25/on-mountain-hut-zero-impact-swiss-alps/

Rodrigues Filho, G., Monteiro, D. S., Meireles, C. D. S., de Assunção, R. M. N., Cerqueira, D. A., Barud, H. S., . . . Messadeq, Y. (2008). Synthesis and characterization of cellulose acetate produced from recycled newspaper. Carbohydrate Polymers, 73(1), pp. 74-82. doi:10.1016/j.carbpol.2007.11.010

Rotor deconstruction. (2020). Retrieved 05/17, 2020, from https://rotordc.com/

SCALE. (2020). Scalite®. Retrieved 07/2, 2020, from https://www.scale.vision/

Sustainability Guide. (2020). *Cradle to cradle*. Retrieved 07/11, 2020, from https://sustainabilityguide.eu/methods/cradle-to-cradle/

United Nations, Department of Economic and Social Affairs, Population Division. (2019). *World population prospects 2019 No. 2: Demographic Profiles* (ST/ESA/SER.A/427))United Nations.

Vartola, A. (2018). Mind-building, Archifo, Finland.

Vezzoli, C. (2014). *The "Material" side of design for sustainability*. In E. Karana, O. Pedgley & V. Rognoli (Eds.), Materials experience: Fundamentals of materials and design. (pp. 105-118). Oxford: Butterworth-Heinemann.

Wastiels, L., Schifferstein, H., Heylighen, A., & Wouters, I. (2012). *Relating material experience to technical parameters: A case study on visual and tactile warmth perception of indoor wall materials.* Building and Environmen, 49(1), 359-367.

Wastiels, L., & Wouters, I. (2012). *Architects' considerations while selecting materials*. Materials and Design, 34, 584-593.

Winchip, S. M. (2011). *Sustainable design for interior environments* (2nd ed ed.). New York: Fairchild Books.

World Commission on Environment and Development. (1987). *Our common future: Report of the world commission on environment and development.* Oxford University Press.

Aknowledgements

A conclusione di questo percorso vorrei ringraziare chi mi ha camminato a fianco, ha supportato le mie scelte, consigliato i nei momenti di indecisione, e spronato a dare sempre il massimo.

In primo luogo ringrazio la professoressa Barbara Del Curto, e i tutor Flavia Papile e Andrea Marinelli per avermi seguito, dedicandomi il loro tempo e garantendomi il loro sostengo. Ci terrei inoltre a ringraziare il professor Matti Kuttinen della Aalto University e la professoressa Giulia Maria Gerosa, per i loro preziosi consigli e stimoli.

In seguito devo ringraziare la mia famiglia, tutta, dai miei genitori, che mi hanno permesso svolgere questo percorso di studi, a Carlo e Miriam, per la loro disponibilità e pazienza, agli zii Claudio e Silvano, e i nonni Rosanna e Franco, i quali non hanno mai perso occasione per dimostrarmi il loro appoggio.

Ringrazio infine tutti coloro che hanno condiviso con me questi anni di studio. Dalle amiche di “una vita” Federica e Elisabetta, che non hanno mai capito cosa studiassi ma hanno sempre saputo supportarmi nel momento del bisogno, alle conoscenze fatte durante gli studi a Milano e a Helsinki. Una menzione speciale va alle mie coinquiline Marta, Elisabetta ed Ilaria, che hanno saputo rendere Milano una seconda casa, a Dafne, per la sua positività, e ai miei compagni e professori della Aalto University, il cui interesse per la sostenibilità mi ha sempre ispirato e guidato.